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Resource Recovery and Waste Reduction
Fourth Report to Congress

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FOURTH REPORT TO CONGRESS

RESOURCE RECOVE

and

WASTE REDUCTION

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FOURTH REPORT TO CONGRESS
RESOURCE RECOVERY AND WASTE REDUCTION

This report (SW-600) was prepared
by the Office of Solid Waste as required by Section 205
of the Solid Waste Disposal Act as amended in 1970
(Public Law 91-512) and was delivered August 1, 1977,
to the President and the Congress

U.S. ENVIRONMENTAL PROTECTION AGENCY
1977

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

August 1, 1977

To the President and the Congress:

I am pleased to submit herewith the Environmental Protection Agency's fourth report on resource recovery and the reduction of solid waste generation, as required under Title II, Section 205, of the Solid Waste Disposal Act as amended in 1970 (P. L. 91-512). Previous reports in this series were issued in February 1973, March 1974, and September 1975. This report reviews the current status of resource recovery and waste reduction in the United States and presents new findings from EPA studies, investigations, and technology demonstration projects.

This is the final report in the present series. The new amendments to the Solid Waste Disposal Act, passed last October as the Resource Conservation and Recovery Act of 1976 (P. L. 94-580), created a revised framework for studying and reporting on solid waste and resource conservation issues. The Act gives EPA wide authority in these areas for research, demonstrations, and studies; this work will be described in a required annual report on EPA's solid waste activities, as well as in other reports and articles. A key element of the law was the establishment of the Cabinet-level interagency Resource Conservation Committee, which has been instructed to study and make recommendations on a broad range of present and proposed national policies affecting resource recovery and the use of our natural resources.

The body of knowledge represented in this series of reports has greatly increased our understanding of the resource-conserving options in waste management. This knowledge, together with the added impetus of the Resource Conservation and Recovery Act, will help us in the years ahead to achieve improved solid waste practices and to devise conservation policies that are prudent in both environmental and economic terms.

Sincerely yours,

DOUGLAS M. COSTLE
Administrator

CONTRIBUTING STAFF

This report is based on a number of EPA contractual efforts and staff analyses, and is the responsibility of the Resource Recovery Division, J. Nicholas Humber, Director. Frank A. Smith provided overall technical supervision and editing. Primary authors included John H. Skinner, Fred L. Smith, and Frank A. Smith of EPA, and William A. Franklin, David Conn, and Marvin Zeldin under contract. Emily Sano of the Management and Information Staff edited the entire manuscript and wrote the Summary. Additional technical contributions were provided by the following EPA staff: Steven A. Lingle, Penelope Hansen, Steven J. Levy, J. Robert Holloway, David B. Sussman, Yvonne M. Garbe, Robert M. Lowe, Lawrence B. McEwen, Robert Randol, Harry Butler, and Thomas Canfield. Chapter reference lists and bibliographical entries in the Appendices were prepared by Frances Lederer of Biospherics, Inc. EPA manuscript typing was done by Mary Williford, Nancy Ziegler, and Brenda Marshall.

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SUMMARY

This report describes the principal developments and findings in the areas of resource recovery and waste reduction, as they apply to post-consumer municipal solid wastes, since the *Third Report to Congress* (September 1975) on these subjects.

BACKGROUND AND PERSPECTIVES

"Resource recovery"–the productive use of waste material–and "waste reduction"–the prevention of waste generation–represent major means of alleviating the problems of solid waste. This is well recognized in the new law, the Resource Conservation and Recovery Act of 1976, which now forms the basis of the Federal solid waste program and which mandates or authorizes a number of programs that directly or indirectly support these resource conservation measures. (While the Act has not yet had significant effect on the practice or development of resource recovery and waste reduction in the country, principal features and implications of the Act are noted in this report.) The nature and causes of the solid waste problem are therefore key parts of the context for understanding the role of resource recovery and waste reduction.

Elements of the Municipal Solid Waste Problem

The solid waste problem includes diverse elements:

- *Growth in solid waste generation.* The product and packaging components of municipal wastes have more than doubled since the early 1950's. Though slowed during 1974-75 due to the recession, waste generation rates are projected to grow substantially over the next 10 to 15 years.
- *Ecological damages of disposal.* Traditionally, incinerator emissions, rats, insects, and trash fires have been of particular concern for public health reasons. More recently widespread pollution of surface and ground waters by runoff and leachate from land disposal sites has been documented. Costs of controlling these effects at acceptable levels nationwide would run to several hundred million dollars per year.
- *Aesthetic effects.* The aesthetic effects of open dump sites, uncollected garbage and trash, and littered streets and landscapes are of general concern. These effects are not directly measurable in dollar terms, although millions are spent annually for litter pickups.
- *Broader environmental implications.* High rates of solid waste production necessarily imply high rates of virgin raw material extraction, processing, and fabrication–the most significant sources of environmental damages.
- *Solid waste disposal as an index of natural resource depletion.* Many have come to regard our high-waste, low-recycle system as inherently wasteful of our endowment of natural resources.

- *Costs of collection and disposal.* The average cost of collecting and disposing of a ton of municipal solid waste is estimated to be close to $30, or almost $4 billion a year nationally. Costs per ton will rise due to increases in land costs, antipollution requirements, and general inflation.

- *Public administration problems.* In addition to rising costs, local officials must increasingly deal with problems of antidisposal zoning, intergovernmental agreements, the location of new disposal sites outside the city or metropolitan area, and the closing of facilities made obsolete by new environmental regulations.

All these problems could be mitigated (although not "solved") by reducing waste generation at the source and increasing resource recovery.

Why is Waste Generation too High and Resource Recovery too Low?

The present high national rate of waste generation (over 1,300 pounds per person per year) and low rate of resource recovery (less than 7 percent of total waste) can be explained in large part as the natural result of an expansive, highly productive economic system endowed with an abundance of natural resources. Historically, cheap supplies of virgin raw materials have encouraged the development of material-intensive technologies and products and discouraged competition from secondary materials. However, there is considerable evidence and theory to indicate that certain national government policies, institutional shortcomings, and failures in our market system of resource allocation have all contributed to a situation where waste generation is too high and resource recovery is too low.

- *Federal policies.* The Federal government has historically played a major role in stimulating natural resource development. Currently, special tax laws relating to mining and forestry and Federal subsidies for raw materials exploration, research, and development all favor virgin raw materials and encourage a materials-intensive economy. In addition, a number of laws and agency policies tend to discriminate against recycled materials and waste reduction measures.

- *Historical disregard for environmental degradation.* Environmental damage costs have been borne mainly by society in general or "third parties" rather than the specific industries and their customers whose decisions caused the damages. By failing to control pollution and other forms of environmental degradation, as a society we have implicitly subsidized the material and energy sectors. By allowing cheap, environmentally damaging waste disposal, we have caused alternative waste reduction and recycling options to be undervalued.

- *Undercosting and noncharging for waste management services.* Conventional accounting systems and financing methods generally lead to understatement of the true costs of solid waste management. In addition, waste generators and disposers seldom see direct charges for these services as they do for other public utilities. These factors cause the services to be undervalued and tend to minimize incentives for waste reduction and resource recovery in both public and private sectors.

Waste Reduction and Resource Recovery Potentials

- *Waste reduction potentials.* By changing product designs or otherwise altering society's patterns of production and consumption, the post-consumer waste stream could conceivably be reduced by 10 percent.

- *Resource recovery potentials.* Up to 25 percent of total post-consumer solid waste could be recycled through source separation (separating out of recyclables by householders, office workers, other waste generators). Large-scale mixed-waste processing systems, now beginning to go into commercial operation, have a greater long-term potential but require much longer lead times, higher capital requirements, and greater risks.

These potentials lie far beyond projections for actual implementation in the foreseeable future in the absence of major shifts in public policies or major unforeseen material and energy shortages.

Concluding Observations

- *Potential benefits from resource recovery and waste reduction cut across many problem areas.* This counsels against *ad hoc* policymaking based on single objectives such as energy saving or waste disposal.

- *Causes of high waste and low-recycling have deep historical roots in the economy and public institutions.* Major progress in waste reduction and resource recovery will require a broadly based, long-term strategy that considers ways of improving the market incentive system as well as more direct efforts at technological and institutional development.

- *A multifaceted, flexible approach is needed.* To be effective and efficient, a national strategy should emphasize a variety of means (from among waste reduction, source separation, and mixed-waste processing options), diversity of local opportunity, and flexibility to change over time with shifts in markets and technologies.

- *Past and present economic incentives and institutions have often been biased against resource recovery and waste reduction.* The sectors "competitive" to resource recovery and waste reduction, that is, conventional disposal and fossil fuels and virgin raw materials, appear to have been subsidized and favored by market failures and government practices.

- *There should be maximum reliance placed on market forces and local decision-making.* However, there is a case to be made for a Federal role in working to correct imperfections in market pricing systems and in modifying government-induced distortions that provide disincentives to resource recovery and waste reduction. Also, short-term Federal efforts to promote technological research and development and provide technical assistance and information seem justifiable in view of past neglect and present needs. As technologies and institutions develop, it should be possible to scale down or phase out many of the programs.

- *A national strategy should reflect an economic logic.* Resource recovery and waste reduction strategies should be consistent with the Federal government's broad commitments to efficiency in government and promotion of improved efficiency in the nation's overall economic system. This concept tends to rule out a "recovery for recovery's sake" or an "energy for energy's sake" approach.

POST-CONSUMER SOLID WASTE GENERATION AND RESOURCE RECOVERY ESTIMATES

- *There was a decline in the estimated amount of post-consumer solid waste generated nationally in 1975* (136.1 million tons) from 1974 (144.1 million). About 8 million tons were recovered for recycling, leaving 128.2 million tons to be disposed of, or 3.2 pounds per capita per day, slightly lower than the 3.5 pounds figure for 1973. The general economic recession, beginning in mid-1974 and deepening into 1975, appears to have had a significant influence on the short-term growth trend of solid waste quantities.
- *The principal impact of the economic slowdown was on paper and paperboard packaging wastes;* these categories accounted for nearly all of the estimated decrease in net waste generation. Overall, the nonfood product components of the waste stream decreased by almost 7 million tons between 1974 and 1975, and this was only partly offset by increases in food and yard wastes.
- *Waste generation rates should rebound in 1976 as the economy recovers,* since there is no present indication that the underlying longer-term economic forces have changed significantly.
- *Wastepaper accounted for 88 percent by weight of materials recovered* for recycling. Overall, allowing for the recession, tonnages of recycled materials have increased during the first half of the decade. However, the percentage of total gross discards recycled has changed hardly at all.
- *Wastes processed for energy recovery have not become quantitatively significant as yet.* In 1975 the 13 energy recovery facilities that were operational processed probably not more than 300,000 tons of waste. Significant capacity additions are in progress, but will probably not reach the million-ton-per-year figure before 1978 or 1979.

WASTE REDUCTION

"Waste reduction" is defined here as prevention of waste at its sources, either by the redesigning of products or by otherwise changing societal patterns of production and consumption.

- *Guidelines for Beverage Containers* were published by EPA in the *Federal Register* on September 21, 1976. Under the guidelines, a refundable 5-cent deposit will be placed on all containers for beer and soft drinks sold on Federal facilities. The purpose is to encourage the return of bottles and cans for reuse or recycling, thereby saving waste management costs, materials, and energy.
- *The Resource Conservation and Recovery Act of 1976* contains provisions for assisting States to develop waste reduction programs and mandates a full investigation of resource conservation by a Federal interagency committee.
- *Recently completed Federal studies* have focused on the resource requirements and environmental impacts associated with particular products; the elasticities of demand for consumer products (data which would help in predicting the effects of price changes on consumption); and operation of existing

Federal programs that directly regulate material use or product characteristics. Analyses of the likely effects of a nationwide beverage container deposit system were completed by EPA and the Federal Energy Administration.

- *Voters in Michigan and Maine approved deposits* for beverage containers in November 1976, while voters in Colorado and Massachusetts rejected deposits.

- *In Oregon, some recently reported effects of the deposit law* include the following: At Blitz, the only local brewery in the State, 90 percent of the containers are refillable bottles, compared with 30 percent before the law. The number of nonlocal beers sold in Oregon has decreased from 29 to 9. Pepsi-Cola now uses refillables exclusively, compared with 65 percent refillables before the law, and reports average number of trips per bottle as ranging from 16 for 26-oz to 27 for 16-oz bottles. Coca-Cola still uses both refillable and nonrefillable containers and reports return rates of 90-95 percent for bottles and 80-85 percent for cans.

- *In Vermont, legislation revising the 1973 beverage container law* was passed in 1975. The new provisions extended labeling requirements for nonrefillable containers and added bans (effective January 1977) on all throwaway glass containers, detachable parts of metal cans, and plastic rings or similar nonbiodegradable devices for connecting containers. Early reported trends following the 1973 law include a 67-percent decrease in the beverage container portion of highway litter, a temporary decline in beer sales, price rises of beer and soft drinks (not necessarily due to the deposit law) a shift toward use of refillables, 8 to 12 trips for soft-drink bottles, increases in employment to handle and transport refillable bottles, and no significant sales or employment impacts on container manufacturers (sales volume in Vermont is relatively small, however).

- *In Minnesota, a December 1976 court decision upheld the 1973 law* giving the State's Pollution Control Agency the authority to review new or revised packaging and the regulations for implementing this authority. An industry suit had challenged the regulations on the grounds that they were unconstitutional, vague, and burdensome.

- *Examples of waste reduction activities in the private sector* include measures taken by the paper industry and newspapers to conserve newsprint (by reducing its weight and changing the format of newspapers) and the attempts of U.S. auto manufacturers to reduce the weight of automobiles to improve gas mileage as mandated by the Energy Policy and Conservation Act.

SOURCE SEPARATION

Source separation—the setting aside of recyclable waste material at the point of generation—is the primary means of resource recovery at present. Most of the 9 million tons of materials recovered (mostly paper) in 1974 was recovered through source separation rather than mixed-waste processing. The potentials are much greater—perhaps 25 percent by weight of municipal solid wastes could theoretically be recovered this way.

- *There is renewed interest in source separation of newspaper and corrugated containers* as a result of the upward trend in the wastepaper market during

1976. The depressed markets of 1974-75 adversely affected newspaper collection programs, but no municipal program that was based on long-term purchase contracts failed during the recession.

- *Demonstrations of multimaterial separate collection.* In 1976 two Massachusetts communities, Somerville and Marblehead, began programs with EPA assistance to demonstrate the extent to which glass, cans, and paper can be economically recovered from the solid waste stream in carefully planned source separation programs. Preliminary results are encouraging. EPA is also assisting two counties in California to develop separate collection programs.

- *Recycling centers* can make recovery of materials possible in rural areas where solid waste is not collected from residences. Nottingham, New Hampshire, is recovering about 50 percent of the waste delivered to its disposal facility by residents. Two other communities, Duluth, Minnesota, and Nez Perce County, Idaho, are being assisted by EPA to develop similar programs.

- *Office paper recycling is spreading*–about 500 organizations are now saving and selling their office wastepaper. Reduced waste management costs, reduced waste volume, and good employee response were among the findings of EPA evaluative studies of these programs.

- *The aluminum industry* reports it now has 1,300 recycling centers. A record 3.9 billion aluminum cans, 25 percent of sales, were turned in at such centers in 1975, 70 percent more than in 1974. The industry currently pays $300 a ton for aluminum cans.

- *Guidelines were issued on April 23, 1976, requiring source separation* and recycling of high-grade paper in Federal office buildings employing 100 or more people, recycling of newspapers from Federal facilities housing 500 or more families, and recycling of corrugated containers from Federal facilities generating 10 or more tons of corrugated per month. Prototype programs will be initiated in each region by the end of 1977. The guidelines also contain recommended procedures for separating other recyclable materials where markets exist or can be developed.

- *Federal agencies will be required in procuring products to select those composed of the highest percentage of recycled material practicable* after October 1978, under the Resource Conservation and Recovery Act.

- *Recycling of used lubrication oil* is the subject of new Federal activity. Provisions of the Energy Policy and Conservation Act of 1975 require the National Bureau of Standards to establish tests to determine equivalency between virgin and refined oils, the Federal Trade Commission to establish labeling provisions as to product quality, and the EPA to provide guidance on acceptable disposal options. The Federal Energy Administration is working toward increasing the amount of used oil made available for recycling.

MIXED-WASTE PROCESSING FOR RECOVERY OF MATERIALS AND ENERGY

Resource recovery from mixed municipal refuse involves the centralized processing of collected raw waste to extract useful energy and recyclable materials. Recovery of energy or fuel is an ingredient in most such systems, as is recovery of ferrous metals. Some systems also include recovery of nonferrous metals and glass. Most systems are designed to divert very large fractions of the incoming waste, leaving no more than 25 percent, by weight, for landfilling.

- *One energy recovery process has been widely used thus far.* Waterwall combustion to produce steam has been widely applied in Europe and is considered a commercially available technology. Another process, recovery of a refuse-derived fuel for use as a supplement to coal in existing boilers, is in early stages of commercial application and has attracted wide interest. Pyrolysis of solid waste has not yet been successfully implemented at commercial scale, but pilot plant operations have been completed.

- *Recovery of ferrous metals is an established technology.* It has been widely applied in instances where waste is being processed for recovery or transport. Composting has been widely practiced in Europe but has been of limited success in the U.S. due to limited markets. Glass and aluminum recovery is being included in some of the newer resource recovery systems now being designed, but the technologies are still considered to be developmental.

- *Initial capital investment estimates* range from $5,000 to $50,000 per ton of daily processing capacity, depending on type of process, plant size, and other factors. While there is still relatively little concrete economic data available for most of the systems, the economics appear favorable for a number of cities and regions, particularly where high disposal costs combine with favorable markets for recovered products.

- *EPA's most recent survey* found that, as of mid-1976, there were 21 operational facilities (many of them pilot or demonstration projects), 10 under construction or in final stages of contract negotiation or procurement, 33 in "advanced planning," and 54 localities at the early stage of having commissioned feasibility studies.

- *Seven different types of technology are represented* among the 21 operational facilities. Thirteen are incinerator types (three older refractory wall units, seven waterwall units, and three new small-scale modular units). The remainder include a composting operation, a wet-pulping fiber recovery demonstration plant, a demonstration pyrolysis plant, a demonstration of methane recovery from landfills, and four plants using the "RDF" (refuse-derived fuel) method employing dry shredding and air classification. Five of the 10 plants that will be coming on-line in the next 2 years will use the dry-shredding technology.

- *Ferrous metal is the only material being almost universally recovered at resource recovery facilities.* Eddy current technology for recovering aluminum is scheduled for intensive testing in 1977; this technique may be nearing commercial application. Among glass recovery techniques, froth flotation will be demonstrated at the San Diego demonstration plant. The system for color-sorting glass tested at Franklin, Ohio, did not eliminate enough contaminants to meet current glass industry specifications as published.

- *Better evaluation of materials recovery processes and their products* will be possible in the near future. A test facility is being constructed by the National Center for Resource Recovery, Inc., with EPA support; the new facilities at Ames (Iowa), Baltimore County, and New Orleans will produce substantial quantities of materials for commercial use; and standards and test procedures for recovered products are being developed by the American Society of Testing Materials, the National Bureau of Standards, and the National Center for Resource Recovery.

- *Net energy efficiencies have been calculated for a number of the energy recovery processes.* Preliminary data indicate that the various processes recover significantly different percentages of the gross energy content of the raw waste input. For example, on a net fuel produced basis, different processes recover as fuel anywhere from 20 to 80 percent of gross input energy (after subtracting processing energy input requirements and the energy content of nonrecovered residuals).
- *Financing:* While there are many variations, almost all facilities have been financed by tax-exempt, long-term debt obligations and are dependent on energy revenue. Most recent projects sell energy products to the electric utility industry. An important development was the favorable ruling by IRS on use of pollution control revenue bonds to finance resource recovery projects.
- *State government involvement* in resource recovery implementation has changed little in the past year: 21 States now have planning or regulatory roles, 11 have authority to underwrite loans or make grants for construction, and 6 have authority to engage directly in procuring and operating facilities.
- *EPA's Resource Recovery Technical Assistance Program* is providing information, consultation, and a small amount of financial aid for planning and implementation to States and communities in need of such assistance.

ENVIRONMENTAL AND ECONOMIC IMPACTS OF NATIONAL RETURNABLE BEVERAGE CONTAINER LEGISLATION

At the request of Congress, EPA has analyzed the environmental and economic impacts of a nationwide refundable deposit on beer and soft-drink containers. The analysis was based on an assumed 5-year transition in the container mix from 1975 to 1980. The analysis also assumed: growth in the refillable bottle share of the market to 80 percent; decline in the use of metal cans to 20 percent of the market; a 90 percent return rate for both refillable bottles and recyclable cans; a 90 percent recycle rate for returned cans; no change in beverage consumption trends; and disappearance of nonrefillable bottles from the marketplace. Some of the major findings based on this scenario were:

- *Litter reduction:* Roadside litter of beverage containers in 1980 would be 60 to 70 percent below levels projected in the absence of deposit legislation. (Beverage containers typically constitute between 20 and 30 percent of total roadside litter by item count and 40 to 60 percent on a volume basis.)
- *Energy savings:* Annual energy consumption for the conventional beverage container system is projected to be 585 trillion Btu by 1980. The returnable scenario projects a reduction of 40 percent (245 trillion Btu's) from that level, a saving in 1980 equivalent to 125,000 barrels of oil per day.
- *Solid waste reduction and material savings:* The beverage container portion of municipal solid waste would be reduced by 70 percent, or 7.2 million tons, in 1980 (a 5-percent reduction in that year's total municipal solid waste).

Estimated annual material savings for the national economy would amount to 500,000 tons of aluminum, 1.5 million tons of steel and 5.2 million tons of glass by 1980.

- *Employment effects:* Employment levels in the container manufacturing and supply industries would decrease by about 80,000 positions by 1980. Actual employee dislocations due to the container deposit would total about one-half of the total job losses, however, since normal attrition in these industries over the 5-year period would affect almost 40,000 jobs. Employment in the beverage filling, distribution, and retailing industries would increase by about 165,000 positions. While the jobs eliminated would generally be higher paying than the jobs gained, the net increase in jobs would result in a $400 million net increase in labor income in 1980.
- *Industrial investment requirements:* Capital expenditures to increase the market share of refillable bottles would total $1.8 billion. Over the 5-year period this is of the same order of magnitude as the current annual investment in one-way container systems.
- *Consumer price impacts:* Projected annual consumer savings would total $2.5 billion by 1980 and $3.2 billion by 1985.

EPA-SUPPORTED RESOURCE RECOVERY TECHNOLOGY DEMONSTRATION PROJECTS

The emphasis of the EPA resource recovery demonstration program has been on large processing facilities that recover resources from mixed municipal solid waste (five projects). Demonstrations are also being supported of multimaterial separate collection (two projects) and recovery of methane from a landfill (one project).

- *The Franklin, Ohio, project,* designed mainly to determine the feasibility of wet processing solid waste to recover paper fiber, was completed in March 1976. According to cost projections for larger plants with nearby users of the fiber, the process appears economically viable. Since markets for this low-quality fiber are limited, however, in future applications of this technology the fiber is likely to be used for fuel.
- *The St. Louis project,* which was also completed in 1976, proved that a refuse-derived fuel could be produced through dry shredding and air classification and fired in suspension with pulverized coal in existing steam-electric boilers without significant adverse short-term effects on boiler operation. Although unit operations have not been optimized and questions remain regarding combined firing with coal, a number of commercial systems have resulted from this demonstration.
- *In Baltimore* the facility that was to demonstrate steam generation through pyrolysis of waste has run into numerous major mechanical problems, many of them attributable to incorrect scaling up from the pilot plant. The city will conduct further performance runs before deciding whether to continue the project or convert the plant into a more conventional solid waste facility.

- *In San Diego County*, the pyrolysis demonstration plant is scheduled to begin operating in June 1977. A liquid oil-like fuel will be produced for use as a supplement to fuel oil in electric utility boilers. Ferrous metal, aluminum, and glass cullet will also be recovered.
- *The State of Delaware* is negotiating with a contractor to design, build, and operate a demonstration plant that will produce refuse-derived fuel for use as a supplement to fuel oil in an existing oil-fired steam-electric boiler. The plant will also handle digested sewage sludge, produce humus by composting, and recover ferrous metals, aluminum, and glass.
- *Somerville and Marblehead, Massachusetts*, have programs to demonstrate the feasibility of weekly curbside collection of paper, glass, and cans using a compartmentalized collection truck. Mixed waste is collected in a regular collection truck. The recovered materials are sold to a processor under a contract with a guaranteed floor price that was negotiated through an open bidding procedure before the programs started. The early results are promising, with the Marblehead program making a profit and Somerville breaking even.
- *Mountain View, California*, has a project to demonstrate the recovery of methane from a typical shallow (40-foot deep) sanitary landfill. The success of the testing program has led to development of a full-scale gas recovery project which is scheduled to be operational by July 1977. The recovered gas will be upgraded and injected into a nearby utility pipeline.

STATUS OF PRODUCT CHARGE STUDIES

As defined in recent Congressional bills, a solid waste product charge is an excise tax on the material content of consumer products entering the solid waste stream. Though varying in specific design details, most product charge proposals to date have had three characteristics in common: (1) a charge (Federal excise tax) on consumer products and packaging tied directly to projected solid waste management costs for the items in question; (2) a special exemption for the use of secondary materials in products and packaging; and (3) provision for redistributing all or most of the revenue yield to local governments for solid waste management purposes.

As reported previously, the product charge concept has a number of desirable incentive features from an economic efficiency standpoint. A waste charge on products would ensure that producers and consumers whose decisions jointly determine the levels of the solid waste management burden will directly bear the costs resulting from their choices, thus providing a direct economic incentive to stimulate desirable waste reduction and recycling efforts.

This report describes EPA research in progress concerning quantitative impacts and economic effects of such an approach. Since our studies are not yet completed, no EPA recommendation of any particular product charge or subsidy measure is warranted at this time.

Assumptions and Preliminary Study Results

The analysis has been conducted on the following base case assumptions: (1) a product charge of $26 per ton for most product wastes and 0.5 cent per unit for rigid containers; (2) levied at bulk material or semi-finished product stages of manufacture; (3) levied on all paper products and all non-paper packaging materials that enter the municipal solid waste stream (these constitute 80 percent of the product contribution to such wastes); (4) a full rebate (credit) for use of recycled material in products; and (5) a phase-in period of 10 years during which the charge would be gradually introduced. Preliminary results based on these assumptions include:

- *Administrative costs:* The degree of complexity and potential administrative overhead costs to the Federal government of implementing a waste charge seem comparable to those of existing Federal product excise taxes. Costs should be less than 1 percent of revenue yield.
- *Recycling effects:* Although the preliminary nature of the analysis suggests that the specific numerical results should be treated cautiously, modeling efforts thus far indicate that significant increases in recycling would result. Recycling of glass, steel, and aluminum packaging would increase severalfold, and paper recycling would more than double.
- *Waste reduction effects:* Adequate estimating models are not available to quantitatively evaluate the range of effects of material cost changes on product designs or packaging material shifts at the producers' level. Estimates of waste reduction based only on consumer responses to induced price changes are on the order of 2 to 3 percent of the product waste stream.
- *Consumer price impacts:* For most products, price increases at the consumer retail level would be less than one-half of a percent. Products such as canned goods and soft drinks with heavy packaging components could show price increases of 2 to 4 percent. The overall impact on the BLS consumer price index (which includes many service and noncharged goods as well as the charged items) would be barely perceptible—on the order of less than two-tenths of 1 percent.
- *Impact on consumer budgets:* Initial analysis indicates that the product charge would cost families in the lowest income group (decile) about $8 per family per year, the highest decile group about $60 per family, and the median U.S. family a maximum of about $30 per year in increased taxes.
- *Impact on government budgets:* The charge scheme would yield about $2 billion per year in Federal revenues by the late 1980's. Since administrative costs would be small, virtually all of this could be made available to local governments either through general revenue sharing or earmarked for solid waste purposes.

Further analysis on this and other product charge and financial incentive measures will be carried out under the interagency Resource Conservation Committee established by the Resource Conservation and Recovery Act of 1976.

Chapter 1

BACKGROUND AND PERSPECTIVES

U.S. households and commercial sources currently generate over 140 million tons of solid waste annually. About 6 percent of this post-consumer municipal waste is recovered for productive uses, the remainder being disposed of in the nation's landfills, incinerators, and open dumps, or littered on city streets and country landscapes. In addition, sewage sludge, demolition and construction refuse, and unrecycled junked autos add further substantial magnitudes to the municipal solid waste disposal burden. These high and rising solid waste volumes have significant adverse consequences in terms of environmental quality, aesthetics, the economy, natural resources implications, and local public administration problems.

Although solid waste generation is an inevitable fact of economic life, it is equally apparent that our society has a broad range of choices regarding the types and quantities of residuals that we produce and the manner in which we deal with them thereafter. It is basically these choices, relating to the nondisposal alternatives for solid waste management, that are the subject of this series of EPA reports on resource recovery and waste reduction. As with the previous three reports, the focus of this fourth report is primarily on "post-consumer" solid waste—the end-product residuals of our system of material flows—as distinguished from the solid waste resulting from mining, agricultural, and industrial processing activities.

As the term has evolved, "resource recovery" is a general concept referring to any productive use of what would otherwise be a waste material requiring disposal. As such, it encompasses narrower concepts such as:

- "Recycling"—reprocessing wastes to recover an original raw material; for example, the steel content from tin cans or the fiber content of wastepaper.
- "Material conversion"—utilizing a waste in a different form of material, such as compost from wastepaper or road-paving material from auto tires.
- "Energy recovery"—capturing the heat value from organic waste, either by direct combustion or by first converting it into an intermediate fuel product.

The initial "extraction" phase of resource recovery is currently performed primarily through "source separation," i.e., the segregation of specific waste materials at their point of discard for concentrated collection and reprocessing. The main alternative to source separation is mixed-waste processing, which involves the centralized processing of collected, mixed municipal wastes to separate out recyclable materials and/or convert mixed fractions into new forms of marketable materials or fuels.

"Waste reduction," on the other hand, involves waste prevention or diminishing the quantity of waste generated. This can be accomplished by redesigning products or changing our consumption patterns so that reduced amounts of materials are required to satisfy our wants. More durable and longer-lived products; reusable rather than throwaway or single-use products and packaging; improvements in the materials themselves so that less material is needed to accomplish the purpose; redesigning products and packaging systems to reduce materials requirements; shifting our consumption habits towards a less materials-intensive "market basket" of goods and services—all are examples of waste reduction approaches.

This *Fourth Report to Congress on Resource Recovery and Waste Reduction* is submitted under Section 205 of the Solid Waste Disposal Act as amended by the Resource Recovery Act of 1970. In October 1976, Congress enacted the Resource Conservation and Recovery Act of 1976 (Public Law 94-

580), which replaces the former provisions of the Solid Waste Disposal Act and adds important new dimensions to the Federal role in solid waste management and resource conservation.

Of most immediate practical significance, the new Act takes major steps to control hazardous waste handling and disposal and to eliminate the use of open dumps as an admissible practice in municipal solid waste management. In addition to benefiting the environment directly, these actions should have far-reaching implications, since, by foreclosing environmentally unacceptable disposal options, which are usually the low-cost options, they will have the effect of placing resource recovery and waste reduction options on a somewhat more equal and equitable competitive basis with land disposal.

In addition to continuing EPA's general research and study, technology demonstration, and technical assistance programs, the 1976 legislation also sets the stage for possible new directions in Federal resource conservation policies. Section 8002(j) established the Resource Conservation Committee, consisting of the Administrator of EPA as Chairman, the Secretaries of Commerce, Labor, Treasury, and Interior, the Chairman of the Council on Environmental Quality, and a representative of the Office of Management and Budget.

The Committee is required to conduct a full and complete investigation and study of all aspects of the economic, social, and environmental consequences of a number of economic and regulatory conservation policies. The Act emphasizes economic market approaches to conservation. These would include modifying existing tax policies, the imposition of waste disposal charges, and the introduction of deposit or bounty systems. The Committee is also to evaluate existing and proposed regulatory policies affecting materials use. Reports must be submitted to Congress on these issues every 6 months. The first of these reports, the Implementation Plan, was recently submitted.

Thus, in the new Act Congress has clearly recognized the close interrelationships between environmental protection, solid waste management, efficiency in the nation's use of materials and energy, and natural resource conservation. The Resource Conservation Committee is the first Cabinet-level committee called upon by Congress to review, evaluate, and recommend policy alternatives cutting across these important aspects of the nation's natural resources and economy. In many respects, the present series of reports to Congress may be regarded as a predecessor to the Resource Conservation Committee studies by providing conceptual background, problem definition, quantitative perspectives, and descriptive review of the state of the art in resource recovery and waste reduction.

This introductory chapter has three purposes: (1) to characterize the nature and magnitude of the municipal solid waste problem; (2) to outline the scope and potentials of resource recovery and waste reduction as solid waste management approaches; and (3) to summarize some general considerations relating to future courses of action.

ELEMENTS AND CAUSES OF THE MUNICIPAL SOLID WASTE PROBLEM

Although solid waste has always been with us, it has only recently come to be regarded as a subject for national concern. A brief review of some of the diverse reasons for this concern will underscore the breadth of the perceived solid waste problems and help in understanding their causes.

Reasons for Concern

Among the many elements of the solid waste problem, the following can be singled out for special attention:

- Growth in waste generation per se
- Environmental damages from waste disposal
- The aesthetics of litter and dumping
- Broader environmental implications
- Waste generation as a reflection of natural resource depletion
- Direct economic costs for collection and disposal
- Other local public administration problems.

All of these issues have received attention in previous reports in this series[1-3] and elsewhere and therefore need only the briefest summary statement.

Growth in Municipal Solid Waste Generation. Residential and commercial solid waste generation now totals about 144 million tons annually, of which more than two-thirds is composed of manufactured products and packaging materials (Chapter 2). In addition sewage sludge is generated at a rate of over 5 million (dry weight) tons per year, and junked autos and building demolition wastes together contribute perhaps another 45 million tons of gross discards. Of these latter three categories of post-consumer solid waste, only the metals in autos and in demolition wastes are salvaged to any extensive degree; the remainder constitutes a substantial portion of the municipal solid waste disposal burden.

Although precise historical data are lacking for most waste categories, analysis of consumption statistics indicates that the product and packaging components of municipal wastes have more than doubled since the early 1950's. Paper, glass, metals, plastics, and rubber wastes have all increased dramatically since World War II. And although slowed recently due to the general economic recession, the national trend is towards substantial future increases in almost all categories of solid waste generation, with less than comparable growth in resource recovery.

This growth in the sheer physical magnitude of post-consumer wastes has had a profound impact on public awareness because of its aggravating influence on all of the associated economic, social, and environmental problems.

Ecological and Public Health Damages from Disposal. Ecological damages attributable to poor solid waste management practices are of increasing concern. Traditionally, the focus was almost exclusively on incinerator emissions and on control of disease-bearing insects and rodents at collection, storage, and dump sites. Though air pollution and sanitation issues are no less important today, our perspectives have broadened to include increased awareness and understanding of important water quality problems resulting from traditional land disposal practices.

Surface and ground water contamination, due to both surface runoff and underground leachate from landfills, has been increasingly documented by EPA and other scientists.[4,5] Ground water contamination is particularly serious because, once it occurs, it is practically impossible to eliminate with present means, and an aquifer may be ruled out as a source of drinking water for decades. Currently about half the U.S. population is served by ground water, and the use of ground water is increasing rapidly.[6]

The need to protect water quality has important implications for the economics of solid waste disposal in locations requiring such protection, since the cost of adequate leachate control in these areas can be expected to more than double the cost of disposal at new landfills.[7] Effects of land disposal on water quality also further emphasize the interrelatedness of the air, land, and water as environmental media for waste disposal.

The environmental damages from uncontrolled disposal and their resulting public health, economic, and social consequences all represent real costs to society of solid waste disposal. These types of social costs have been variously termed "external costs" or "hidden costs" in that they do not show up either on the accounting statements of individual waste generators or in the solid waste budgets of city governments, but rather are borne indirectly and often anonymously by the damaged parties. As with aesthetic costs, they are not priced in the marketplace nor can they be readily measured in conventional monetary terms, and thus meaningful nationwide estimates of these important categories of social costs have not thus far been developed. They are no less real, however, and would most certainly be reduced by more extensive use of waste reduction and resource recovery approaches.

Aesthetic Effects. To a great many people, the solid waste problem is most apparent in its aesthetic dimensions—the aesthetics of uncollected garbage and trash, dump sites, incinerator smoke, garbage washed up on beaches, and littered streets and landscapes. Tens of millions of dollars are spent annually by State and local agencies on street and highway litter pickups. Such expenditures are crude and incomplete proxies for society's willingness to pay for a more aesthetically satisfying environment, but they do signify that society places a considerable value on the aesthetic quality of the environment, aside from ecological damage and public health aspects.

Broader Environmental Implications. Another fundamental dimension of the environmental implications of high rates of post-consumer solid waste disposal becomes evident when we view the national economy as an integrated system of material flows. The present system might be characterized an "open-ended" or "high-throughput" economy in terms of the way in which final demands for material goods and services are satisfied. We produce an extremely high rate of material flow per person and per unit of national income or economic welfare. We do this by such means as satisfying an increasing portion of our consumer wants with single-use or disposable items rather than reusable commodities, utilizing shorter-lived rather than longer-lived durable goods, and recycling very little of the resulting high flow of wastes.

It has been abundantly documented by EPA and others that virgin material extraction and the initial raw materials refining and processing activities are by far the most significant sources of the nation's environmental damages. These damages include many forms of ecological disruption from mining and timber harvesting as well as air and water pollution. (See Appendix E for a bibliography on this topic.) Virgin material extraction and processing are also disproportionately high consumers of energy. Thus the magnitude of the solid waste problem is directly correlated with most other environmental degradation problems which originate earlier in the production sequence of the economy's system of material flows.

Waste reduction approaches, as alternatives to present materials-intensive systems for satisfying final consumer needs, produce comparatively very low system-wide industrial pollution and other forms of environmental degradation, while effectively eliminating post-consumer waste generation. Less obvious, but also well documented, is the fact that virtually all resource recovery technologies also produce substantially lower system-wide environmental damage potentials and also require far less energy than counterpart virgin-materials supply sequences.[8-10]

Actions taken to reduce material throughput and recover post-consumer material residuals will thus generally yield environmental protection benefits throughout the economic system and not only at municipal solid waste disposal sites. In effect, this represents substitution of low-polluting systems for high-polluting systems of production and consumption.

Solid Waste Disposal as an Index of Natural Resource Depletion. The same perspective on material flows leads to the conclusion that the rate of post-consumer solid waste disposal can be regarded as a useful quantitative measure of the rate of depletion of virgin natural raw material resources. Thus, a high-waste, low-recycle economy necessarily implies high rates of virgin raw material extraction and processing (with attendant high industrial energy demand) and/or high rates of imported raw material and fuel resources. This, in turn, means that the rate of depletion of the higher quality natural resources will be faster the less we rely on waste reduction and resource recovery as material and energy conservation alternatives to the "high-throughput" system of satisfying material wants.

There is honest disagreement among natural resource economists as to the seriousness of the need to adopt conservation measures at this time,[11] and as to appropriate measures for evaluating the present and future social value of conserving (i.e., postponing use of) virgin resource stocks.[12,13] Nevertheless, few would argue that resource conservation is of no consequence in the modern world.

Direct Costs of Collection and Disposal. EPA estimates that the average cost for collection and disposal of post-consumer municipal solid waste in 1976 was close to $30 per ton, or almost $4 billion a year for the U.S. as a whole. These costs have probably doubled within the past 6 to 8 years; and they include only direct expenditures (both public and private) relating to existing disposal practices, which are considered environmentally inadequate for the majority of U.S. communities. In addition to general inflation and growth in the waste stream itself, direct real national costs will rise in the future due to rising land values, longer haul distances to new outlying disposal sites, and to increased requirements for environmental protection at disposal sites and emission controls for incinerators. At least in part, the increase in direct costs of waste handling and disposal will come as a direct consequence of the implementation of the Resource Conservation and Recovery Act, especially Section 4005 which mandates the elimination of open dumps by 1983.

Public Administration Problems. Although ranking below such local public expenditure items as health, education, welfare, streets, public safety, sewage, and water, solid waste collection and disposal services nonetheless occupies a significant position in local government budgets.[14] As discussed, direct costs of collection and disposal have been increasing steadily, and a very large part of the total is reflected in municipal budgets.

However, the public administration problems go beyond the questions of cost and finance. Increasingly, they also include problems of zoning, of locating new disposal sites outside city limits, and of achieving broader regional management approaches. In many respects, the city and county management problems posed by high and rising solid waste flows often appear disproportionately large, even relative to their budgetary position.[15]

Summary. The "municipal solid waste problem" can be viewed from different perspectives as parts of many diverse problems having to do with waste management, environmental protection, natural resource conservation, and economic welfare. All these problems could be mitigated, although not necessarily "solved," through properly chosen reductions in waste generation rates and increases in resource recovery rates. However, before considering the feasibility and desirability of expanding these solid waste management approaches, it is important first to question basic causes. This involves two paramount questions: Why are solid waste generation rates too high (over 1,300 pounds per person per year)? and, Why are resource recovery rates too low (less than 7 percent of total waste generation)?

Why So Much Waste and So Little Recycling?

To a very significant degree, our high and rising levels of solid waste generation can be explained as the natural result of an expansive, highly productive market economy richly endowed with an abundance of accessible natural resources. This combination has made for relatively cheap virgin materials and energy, which in turn has had the dual effects historically of encouraging extensive use of materials and energy, on the one hand, and of discouraging competition from secondary (recovered) resources on the other.

These forces have been augmented, however, by a variety of explicit and implicit public policies and by a number of important shortcomings in the market pricing system which also have guided our resource allocation decisions. Thus, for a number of reasons, to be discussed below, virgin raw material and fuel costs have historically been made "artificially" low in relation to the levels that would have prevailed under a system in which raw material markets accurately reflected the full social costs of material use and were less biased by public policies. In this sense, virgin material use and concomitant waste generation have been made "too high." Similarly, resource recovery has been "too low" because of the explicit and implicit advantages afforded virgin supplies. Some of these policies and market conditions are as follows:

Federal Policies Stimulating Natural Resource Development. The Federal Government has always played a major role in stimulating and encouraging natural resource development. In the last century, a series of public land acts, railroad development grants, and mining and minerals policy laws generally opened the country to resource exploration and development. More recently, special Federal tax laws favoring mineral extraction (percentage depletion allowances and foreign tax credits) and timber and pulpwood harvesting (capital gains treatment) have reinforced the tendency towards inexpensive virgin raw materials.[16,17]

Perhaps more important in recent years, however, have been the Federal (and some State-level) subsidization of mineral exploration (carried out by the U.S. Geological Survey), mining and processing research and development (U.S. Bureau of Mines), and agricultural and forestry research and development (U.S. Department of Agriculture).

EPA does not necessarily question the historical validity of any of these acts or policies favoring expansive natural resource development. Under modern circumstances, however, certain of these policies have come under question. Others, especially those in the research and development area, might also be reconsidered in terms of the stimulus they provide to virgin material consumption. For example, when financed out of general tax revenues, these R&D costs do not become reflected in the market prices of the relevant raw material and energy products, thus understating the full social costs of these commodities in the marketplace. In effect, this represents a hidden subsidy that encourages higher market demand for these materials and less economy in their use than the free market would otherwise have encouraged.

Historical Disregard for Environmental Degradation. Until quite recently, the American economic and political systems exhibited a general disregard for environmental degradation. This was equally true in relation to mining and processing as it was for municipal solid waste disposal. Environmental damage costs of mining and processing have been borne mainly by society in general or by "third parties" rather than the specific industry and its customers whose joint economic decisions gave rise to the environmental damage. For this reason, market prices for materials and fuels have failed historically, and in large part still fail, to reflect the full social costs of production, thus providing inaccurate price signals for resource allocation.[18] Once again, the result has been an implicit stimulus to a more materials-intensive economy.

At the other end of the material flow sequence, post-consumer solid wastes have also been creating environmental damage costs for society. These have not been accounted for in community solid waste management budgets, nor have they been reflected back to waste generators as an inherent part of the total "life cycle" cost of using and disposing of material goods. Here, again, is another example of an implicit subsidy to material consumption.

Others Factors Causing Costs of Solid Waste Services to be Obscured. In addition to the market's failure to account for environmental damage costs, a number of other institutional factors typically obscure and understate the full social costs of the solid waste collection and disposal services themselves.

The first set of factors relates to three types of undercosting typically encountered at the local municipal services level. The first is the fact that municipal and county solid waste accounting systems often segregate land and equipment costs in separate capital accounts, and the current interest and amortization often do not get explicitly recognized in the solid waste budget. The second factor is that foregone property tax revenues on lands set aside for public waste processing and disposal sites are almost never explicitly recognized as a community cost attributable to the waste management function. They are, of course, paid through higher taxes on other properties. Finally, municipal purchases of land and equipment are financed by public sector bonds, the interest on which is exempt from Federal taxes. While reducing local government costs of providing solid waste services, the differential interest rate subsidy is paid out of higher Federal taxes on other sources of income. All of these accounting, financing, and taxing practices have tended to make it appear that local solid waste services are less costly than they really are.

Of greater significance than these cost accounting factors, however, is the fact that three-fourths of U.S. communities finance their solid waste management systems out of general tax revenues (mainly property taxes) rather than through user fees.[18] This means that most households, and many commercial enterprises as well, never see a specific bill or charge of any kind for this service, as they do, for example, for electricity or other public utility services. Many cities that do employ user fee systems to finance solid waste services charge lump-sum amounts that are not related to quantities handled.

Though possibly justifiable from other viewpoints, all of these practices involve the undercosting of services and/or the noncharging of the economic costs to the waste producers in the material flow system. By making the services appear costless to those utilizing them, noncharging has the overall effect of minimizing or negating any possible economic incentive towards reducing waste generation or encouraging local public or private resource recovery options.

Other Federal Policies Inimical to Resource Recovery. Congress has long recognized that a number of public laws and Federal agency policies may have tended to discriminate against recycling or waste reduction. Although preliminary steps have been taken to evaluate and improve upon some of these situations, problems may still remain regarding the following:

- Rail freight rates, administered by the Interstate Commerce Commission, that may favor virgin over secondary materials. An EPA study found no decisive pattern, but did present evidence that suggested possible rate biases against ferrous scrap, glass cullet, and reclaimed rubber, and possible favoring of scrap rubber, scrap aluminum, and wastepaper.[19] As the result of a Congressionally mandated study, ICC in February 1977 ordered reductions in the freight rates in certain geographic areas for certain secondary materials, including reclaimed rubber and glass cullet. ICC found no cause for lowering rates for ferrous scrap or wastepaper. Further investigation was ordered of rates for some other secondary materials.

- Pejorative product labeling requirements that unnecessarily or incorrectly introduce purchaser biases against products manufactured from secondary or reclaimed raw materials. The Wool Labeling Act and the Federal Trade Commission labeling requirements on reclaimed lubricating oil are cases in point. The FTC is also currently reviewing its regulations in this field.

Conclusions

To a significant degree, our post-consumer solid waste generation rates are higher than they should be and our resource recovery rates are lower than they should be from the perspectives of national economic efficiency and general public welfare. Our high-throughput, open-ended economic system of material flows has been historically biased by a large number of explicit public policy measures and implicit public administration shortcomings, and by some important shortcomings in the market system itself. The overall effect historically has been a failure of both raw material and product markets to signal a correct pattern of incentives in costs and prices. This situation is reflected today in the intensification of many perceived national concerns falling under the general rubric of "the municipal solid waste problem."

ALTERNATIVES TO DISPOSAL: RESOURCE RECOVERY AND WASTE REDUCTION AS RESIDUALS MANAGEMENT TOOLS

The Potentials

The *Third Report to Congress* presented results from an unpublished EPA analysis of the technical potentials for waste reduction and resource recovery relative to projected 1985 waste generation levels.[20] Because we consider these potentials to be significant, the highlights are repeated below. The estimates are based only on technical possibilities within the state of technology that now exists or that can reasonably be expected to be available within the next 5 to 10 years. It should be emphasized that many elements of these estimates have not yet been subjected to economic feasibility or benefit-cost evaluations. They are not being suggested as national goals but only as first-step results in the evaluation of future potentials.

Waste Reduction Potentials. Based on what seemed to be a reasonable set of assumptions, EPA projected that the 1985 gross discard stream (approximately 200 million tons) could be reduced by up to 20 million tons (10 percent of total waste; 15 percent of nonfood product waste). The assumptions for this scenario included: an 80-percent nationwide shift to refillable beer and soft-drink containers; a major shift to more durable passenger car tires (continuation of current industry trend); and a general 10-percent reduction in other nonfood product and packaging wastes per unit of final sales, based on a variety of material conservation measures. Altogether, these measures would result in decreases in gross discards of glass by 40 percent, rubber tires by 40 percent, aluminum by 30 percent, ferrous metals by 15 percent, and other materials (including paper) by 10 percent.

Actually implementing such a scenario would not be an easy matter, especially since there are likely to be apparent adverse impacts on a number of key primary industries. Nevertheless, the majority of the changes in question would most likely result in lower total cost to consumers.[21,22] Furthermore, if phased in over a 10- to 15-year period, the primary impact would in most cases occur as a reduction in the net *growth* of product outputs and employment for the specified industries, rather than as an absolute decrease in output and employment from their present levels.

Resource Recovery Potentials. EPA has estimated that a maximum feasible nationwide source separation effort could recycle approximately 25 percent of the nation's total gross discards, compared with about 6 to 7 percent currently. Based on nonfood product waste only, this would amount to about 35 percent, or three and one-half times the present 10-percent recovery rate. Based on the projected 1985 gross discards of 200 million tons (without waste reduction), this maximum source separation program could yield 45 to 50 million tons of paper, metals, glass, and rubber for recycling.

Though this yield figure appears extremely high, it is not without some precedent—recycle rates during World War II were apparently at comparable levels for wastepaper, metals, and rubber. That public participation rates can indeed be quite high given the necessary incentive is currently being demonstrated by the aluminum industry, which reports that, during

1975, 25 percent of all-aluminum cans were returned for recycling at a price of 15 cents per pound.[23]

Mixed-waste processing potentials, including both material and energy recovery, are generally thought to be restricted by logistics and other factors to the metropolitan or urbanized areas of the country. If this is so, then based on an assumed 80-percent recovery efficiency factor for the urbanized U.S. (which generates 70 percent of the nation's waste), the maximum technically feasible recovery could not be greater than about 56 percent (80 percent times 70 percent) of the nation's "available" or deliverable waste stream. For 1985, this would then amount, at most, to about 112 million tons of the nation's estimated 200 million tons of gross waste.

For a number of reasons, this should be considered only an approximation of the maximum level possible. In the first place, the amount available for processing in mixed-waste systems will be subject to the influences of both waste reduction, if any, and prior source separation activities. In the second place, the amount "available" will have very little to do with the amount that is likely to be processed, even though it is probably "technically feasible" to process almost all that is available. No estimates have thus far been made to ascertain the economically feasible or desirable (in cost-benefit terms) future nationwide levels of mixed-waste processing. EPA and contractor estimates of mixed-waste plants expected on line, based on present trends and policies, indicate that 10 to 20 million tons of materials could be diverted from conventional disposal through such plants by 1985.

Economic Considerations

Our studies have indicated that as far as technical feasibility is concerned, waste reduction and resource recovery opportunities available now or in the near future are such that very sizable potential reductions in solid waste generation and attendant disposal problems could be achieved. Beyond the essential prerequisite of technical feasibility, however, economic considerations largely determine the selection of options in waste reduction, resource recovery, and conventional disposal. For private industry, consumers, and local governments, decisions to select or reject available waste reduction and resource recovery measures will hinge largely on comparative market values relating to such factors as alternative product and packaging designs, prices of virgin or secondary raw materials and fuels, and cost of available and permissible solid waste disposal options. Thus, the competitive marketplace will determine the economic practicality of nondisposal alternatives and the degree to which they are introduced over time.

At present, it appears that some waste reduction and resource recovery options stand a good chance of economic survival and expanded use on their own merits under present market conditions. Many more, however, will not appear "practical" at the present time from private business or local government perspectives. Costs will be too high or rates of return on investment will be too low for these to be the preferred alternatives under conventional cost-accounting practices.

In this respect it should be reiterated that many of the market values upon which such decisions are based appear to understate, possibly significantly, the true social values of resource recovery and waste reduction options. This is due to the previously discussed market imperfections, public sector policies favoring virgin resources, and shortcomings in local waste management cost-accounting practices. Thus, from a broad national viewpoint, it can be argued that private sector and local government decisions under present conditions will not achieve an economically desirable degree of waste reduction or resource recovery.

This does not mean that we should be prepared as a nation to embrace every waste reduction or resource recovery proposal as a means of advancing the public welfare. It does strongly suggest, however, that the Federal government may well have an important corrective role to play in formulation of a national strategy for waste reduction and resource recovery.

In considering the economics of resource recovery and waste reduction over the longer term, it should also be recognized that the economic values in this field may well change quite rapidly over time. For example:

- If world raw material and fuel prices increase due to conditions of increased scarcity or for political reasons, nondisposal solid waste options will increase in social value.
- If society places a higher value over time on environmental aspects of solid waste disposal, nondisposal options increase in value.

- If technological innovations increase the attractiveness of waste reduction options or decrease the cost or improve the competitive quality of recovered materials or fuels, then the economically desirable waste reduction or recovery level is increased.

In a rapidly changing world, dynamic factors such as these can play a deciding role in determining the economic future of waste reduction and resource recovery.

CONCLUDING OBSERVATIONS

This *Fourth Report to Congress* does not present specific recommendations for legislation or other Federal policy changes. As noted in the introduction, the Resource Conservation and Recovery Act of 1976 was just passed in October. This Act sets forth new objectives in solid waste management relating to environmentally safe handling and disposal of wastes and conservation of energy and materials. Key provisions establish regulation of hazardous waste management and prescribe steps to end inadequate land disposal of all wastes. The Act also created a Federal interagency Resource Conservation Committee, chaired by the Administrator of EPA, to conduct a detailed review of financial and other national incentive policies over a 2-year period. Thus, a new focus on national waste management and conservation policy has been created.

Based on findings described in this and previous reports to Congress, EPA has reached a number of general conclusions concerning the nature and significance of resource recovery and waste reduction as ways to deal with long-term national problems. These conclusions, which are summarized below, are consonant with the new directions indicated in the Resource Conservation and Recovery Act and have continuing implications for the design of national policy.

- *Resource recovery and waste reduction produce multifaceted benefits.* The benefits from resource recovery and waste reduction cut across many problem areas, including those of local solid waste management, environmental protection, energy supply and conservation, and national materials policy. There is also considerable evidence that appropriate increases in both of these activities would increase the nation's overall economic efficiency. This counsels against ad hoc policymaking based on a single objective such as "energy" or "waste disposal" alone.

- *The causes of our solid-waste-related problems have deep historical roots in the economic and institutional structure.* EPA analysis suggests that the nation's solid-waste-related problems are to a great extent manifestations or results of a high-technology economy geared to an imperfect set of market incentives which, partly due to past public policy, have tended to undervalue material conservation and resource recovery activities. In addition, social and political institutions for waste management and environmental protection have, until very recently, been either entirely lacking or focused only on very narrow and symptomatic aspects of the broader problems related to our uses of materials and energy. As a result, both our technologies and our social institutions for dealing with these issues are underdeveloped.

This view of causes suggests that there is no quick or easy solution. On the contrary, it implies the need for a broadly based, long-term national strategy that considers various possibilities for altering market incentive structures as well as efforts at technological development and institutional improvements.

- *A great many technical approaches are available; all have particular advantages and disadvantages.* EPA finds that no single technical approach (such as mixed-waste processing, source separation, or waste reduction) can "solve" the solid waste problem; a broad range of tools needs to be employed if significant national progress is to be made. Regardless of their other specific merits or disadvantages, certain approaches are more appropriately undertaken at a national level, others at the State or local level. Some are more appropriate for small communities or rural areas, and some are best adapted for particular local markets.

These conclusions imply that national and local strategy formulation should continue to be based on evaluation of a diversity of approaches, including a full range of resource recovery technologies and waste reduction possibilities. They also argue strongly for preserving flexibility in decision-making at both the municipal and private enterprise levels. They do not imply that resource recovery and waste reduction will or should replace land disposal in cases where land disposal can be a least cost and environmentally acceptable option.

- *Past and present economic incentives and institutions have often been biased against resource recovery and waste reduction.* The economic feasibility of increased resource recovery and waste reduction activities is dependent upon current costs of competitive waste disposal services (landfilling) and prices of competitive fossil fuel and virgin raw materials. However, these competitive sectors appear to have been subsidized and favored in a number of ways by market failures and government practices, to the detriment of resource recovery and resource conservation. As discussed above, the list of factors includes:

  Undercosting and noncharging for waste management services in local level accounting systems

  Employing environmentally unsatisfactory, low-cost solid waste disposal methods

  Historical failure to control pollution and other environmental degradation in mining, farming, processing, and manufacturing sectors, thus underpricing the true costs of virgin materials and fossil fuels

  Various forms of Federal subsidies, including percentage depletion for minerals extraction and capital gains treatment of wood harvesting, extensive R&D, and other promotion of the virgin raw materials sector

  The general inability of our market structure to reflect the total life-cycle costs of material use back to points of product design and purchasing decisions, thus failing to correctly price various raw material and product options

The Resource Conservation and Recovery Act of 1976 addresses the land disposal question, and our general air and water pollution control regulations have begun to require some measure of cost internalization of pollution control on the part of industry. However, much remains to be done regarding these and other market shortcomings and public sector biases. Restructuring market disincentive factors should encourage resource recovery and waste reduction across a broad national front, with general benefit for the economy as a whole.

There are also two broad philosophical propositions that EPA believes should form the basis for long-term policy formulation in the field of national resource recovery and waste reduction policy. These relate to the appropriate role for the Federal government and the question of economic rationality:

- *Many Federal activities in the resource recovery and waste reduction field may be justifiable in the short run, but can be minimized in the long run.* In accordance with reliance on free markets and decentralized decision-making, the long-run goal should be to minimize the direct participation of the Federal government in day-to-day resource recovery and waste reduction decisions. It would not be inconsistent with the principle of reliance on market forces and local government decisions, however, for the Federal government to work toward correcting imperfections in market pricing systems and modifying government-induced distortions judged to be long-term causes of the problem.

  A case can also be made for an active short-term Federal role in promoting technical research and development in these fields to "catch up" after a history of past neglect and market imperfections. Moreover, in many instances, total social benefits will exceed the private industry or local government benefits from particular lines of technological development. Federal technical assistance and information programs can be supported on similar grounds. However, as the technologies and institutions develop over time, it should be possible to scale down or phase out many of the supporting Federal activities now considered essential to a balanced short-term strategy.

- *A national strategy should reflect an economic logic.* Resource recovery and waste reduction strategies should be consistent with the Federal government's broad commitments to efficiency in government and promotion of efficiency in the nation's overall economic system. This proposition has a number of important implications. For example, it tends to rule out a "recovery for recovery's sake" or an "energy for energy's sake" approach. It also suggests that technological feasibility alone is an insufficient criterion for Federal action.

  EPA recognizes that sound benefit-cost analysis in these fields can be extremely difficult due to the large number of system interrelationships and major methodological problems in assessing the economic benefits of natural resource conservation and pollution abatement measures. Nevertheless, sound policy planning in these fields requires increased application of economic logic.

REFERENCES

1. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; first report to Congress. 3d ed. Environmental Protection Publication SW-118. Washington, U.S. Government Printing Office, 1974. 61 p.
2. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.
3. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and waste reduction; third report to Congress. Environmental Protection Publication SW-161. Washington, U.S. Government Printing Office, 1975. 96 p.
4. Brunner, D. Gas and leachate from land disposal of municipal solid waste; summary report. Cincinnati, U.S. Environmental Protection Agency, Solid and Hazardous Waste Research Division. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)
5. Miller, D. W., F. A. DeLuca, and T. L. Tessier. Ground water contamination in the Northeast States. Washington, U.S. Government Printing Office, 1974. 325 p.
6. U.S. Environmental Protection Agency, Office of Water Supply and Office of Solid Waste. Waste disposal practices and their effects on ground water; the report to Congress. 1977. 511 p.
7. Shuster, K. A. Leachate damage assessment; an approach. Environmental Protection Publication SW-172. Washington, U.S. Environmental Protection Agency, 1976. (In preparation.)
8. Ziegler, R. C., et al. [Calspan Corporation]. Environmental impacts of virgin and recycled steel and aluminum. Environmental Protection Publication SW-117c. U.S. Environmental Protection Agency, 1976. 125 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-253 487.)
9. Gordian Associates, Inc. Environmental impacts of production of virgin and secondary paper, glass and rubber products. Environmental Protection Publication SW-128c. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)
10. Hunt, R. G., et al. [Midwest Research Institute]. Resource and environmental profile analysis of nine beverage container alternatives; final report. v. 1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p.
11. Brown, G. M., and B. Field. Implications of alternative measures of natural resource scarcity. Presented at Annual Meeting, American Economic Association, Atlantic City, Sept. 18, 1976.
12. Mishan, E. J. Criteria for intergenerational welfare comparisons. Presented at Annual Meeting, American Economic Association, Atlantic City, Sept. 18, 1976.
13. Page, T. An economic basis for materials policy. Baltimore, Johns Hopkins Press, 1976.
14. U.S. Bureau of the Census. Governmental finances in 1972-73. Series GF 73 No. 5. Washington, U.S. Government Printing Office, Oct. 1974. 56 p.
15. Cities and the nation's disposal crisis. Washington, National League of Cities and U.S. Conference of Mayors, Mar. 1973. 46 p. Reprinted, [Cincinnati], U.S. Environmental Protection Agency, June 1973.
16. Booz-Allen and Hamilton, Inc. An evaluation of the impact of discriminatory taxation on the use of primary and secondary raw materials. Environmental Protection Publication SW-101c. U.S. Environmental Protection Agency, 1975. 148 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-240 988.)
17. Anderson, R. C., and R. D. Spiegelman [Environmental Law Institute]. The impact of the Federal tax code on resource recovery. U.S. Environmental Protection Agency. 1977. (Distributed by National Technical Information Service, Springfield, Va. as PB-264 886.)

18. Kneese, A. V. Natural resources policy 1975-85. Albuquerque, University of New Mexico, Department of Economics, Apr. 1976. p. 20. (Program in resource economics. Working paper series no. 1.)

19. Moshman Associates, Inc. Transportation rates and costs for selected virgin and secondary commodities. U.S. Environmental Protection Agency, 1974. 234 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-233 871.)

20. Smith, F. A. Technical possibilities for solid waste reduction and resource recovery; prospects to 1985. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Dec. 10, 1974. 18 p. (Unpublished paper.)

21. Westerman, R. R. The management of waste passenger car tires. Ph.D. Dissertation, University of Pennsylvania, Philadelphia, 1974. 239 p.

22. Summary of the environmental and economic impacts of national returnable beverage container legislation. (Unpublished research by the Resource Recovery Div., EPA, 1976.)

23. Aluminum statistical review 1975. New York, Aluminum Association, Inc., [1976]. 64 p.

Chapter 2

POST-CONSUMER SOLID WASTE GENERATION AND RESOURCE RECOVERY ESTIMATES

Beginning with the second report to Congress in this series (March 1974), EPA initiated a new series of municipal solid waste estimates based on a material flows estimating procedure.[1,2] The estimates cover the post-consumer residential and commercial waste sources and types that comprise the major portion of typical municipal collections. Excluded are data on mining, agricultural, industrial processing, and demolition and construction wastes, sewage sludge, and junked autos and other obsolete equipment wastes, which are not covered in this report.

This chapter provides an update on the EPA estimates of national post-consumer solid waste generation and recycling through 1975, together with selected historical comparisons covering the period from 1971 and projected future trends. The tabular formats, definitions of waste categories, and estimating methods are essentially the same as those employed in the last two annual reports in this series and as described in detail in other publications.[3-5]

The material flows approach utilizes detailed U.S. government and industry trade association statistics on material consumption and product shipments to household and commercial sectors in deriving solid waste generation estimates. While this approach yields reasonably accurate estimates for most of the manufactured goods components of the waste stream, the food and yard waste estimates can be considered only rough approximations. In addition, the estimates presented are indicative only of U.S. nationwide totals or averages. Since there is considerable regional variation in waste generation, collection, and recycling rates, these nationwide figures should not be used for local planning purposes.

DISPOSAL ESTIMATES FOR 1975 AND RECENT TRENDS

Estimates of U.S. post-consumer solid wastes disposed of in 1975, by material types and by major product-source categories, are presented in Table 1. "Net waste disposed of" includes collected and uncollected wastes disposed of by incineration, landfilling, dumping, and littering, after accounting for amounts of materials recycled.

As in other recent years, paper, glass, and metals dominated the waste material categories, and the containers and packaging group dominated the major product-source categories. Overall, nonfood products accounted for about 61 percent of the "as-generated" weight of total net waste, with food wastes and yard wastes (grass clippings, leaves, etc.) also contributing very substantial portions.

The figures show a rather sharp decline in total waste disposal of over 6 million tons, from 1973-74 highs of about 135 million tons to just over 128 million tons in 1975 (Table 2). In per capita terms, this represents a decrease to 3.2 pounds per person per day in 1975 from 3.5 pounds in 1973.

The general economic recession beginning in mid-1974 and continuing well into 1975 thus appears to have had a significant influence on the short-term growth trend of solid waste quantities. Overall, the nonfood-product component of the waste stream decreased by almost 7 million tons during 1974-75, and this was only partly offset by estimated increases in food and yard wastes. The principal impact of the economic slowdown was reflected in paper and paperboard packaging, which accounts for most of the estimated decrease.

However, it should be explained that some portion—perhaps a significant portion—of the apparent decrease in 1975 packaging and other paper and board waste is attributable to shortcomings in the estimating procedure and data available rather than to a real decrease in post-consumer waste. The estimating problem is due to abnormally large reductions in converter inventories, which was reflected in the extremely large production cutbacks at paper and board mills during the last quarter of 1974 and the first half of 1975. Actual consumption of paper and

TABLE 1

MATERIAL FLOW ESTIMATES OF RESIDENTIAL AND COMMERCIAL POST-CONSUMER NET SOLID WASTE DISPOSED OF, BY MATERIAL AND PRODUCT CATEGORIES, 1975*†

Material category	Product category (In millions of tons, as-generated wet weight)*‡							Totals			
								As-generated wet weight‡		As-disposed wet weight§	
	Newspapers, books, magazines	Containers, packaging	Major household appliances	Furniture, furnishings	Clothing, footwear	Food products	Other products	Million tons	Percent	Million tons	Percent
Paper	9.8	19.1	tr.	tr.	–	–	8.3	37.2	29.0	44.9	34.9
Glass	–	12.2	0.1	tr.	–	–	1.0	13.3	10.4	13.5	10.5
Metals		5.9	2.1	0.1			4.0	12.1	9.6	12.6	9.8
Ferrous	–	(5.2)	(1.8)	(0.1)	–	–	(3.7)	(10.8)	(8.6)		
Aluminum	–	(0.7)	(0.1)	tr.	–	–	(0.1)	(0.9)	(0.7)		
Other nonferrous	–	–	(0.2)	tr.	–	–	(0.2)	(0.4)	(0.3)		
Plastics	–	2.7	0.1	0.1	tr.	–	1.5	4.4	3.4	4.9	3.8
Rubber and leather	–	tr.	tr.	tr.	0.7	–	2.6	3.3	2.6	3.4	2.6
Textiles	–	0.1	tr.	0.6	0.5	–	0.9	2.1	1.6	2.2	1.7
Wood	–	1.8	tr.	2.6	–	–	0.5	4.9	3.8	4.9	3.8
Total nonfood product waste	9.8	41.7	2.3	3.4	1.2	–	18.9	77.5	60.5	86.5	67.3
Food waste	–	–	–	–	–	22.8	–	22.8	17.8	19.1	14.9
Total product waste	9.8	41.7	2.3	3.4	1.2	22.8	18.9	100.3	78.3	105.6	82.2
Yard waste								26.0	20.2	20.9	16.3
Misc. inorganics								1.9	1.5	2.0	1.6
Grand total								128.2	100.0	128.5	100.0

*Office of Solid Waste, Resource Recovery Division, and Franklin Associates, Ltd., revised January 1977.

†Net solid waste disposal defined as net residual material after accounting for recycled materials diverted from waste stream.

‡"As-generated" weight basis refers to an assumed normal moisture content of material in its final use prior to discard, for example: paper at an "air-dry" 7 percent moisture; glass and metals at zero percent. Total waste, including food and yard categories, estimated at 26 percent moisture.

§"As-disposed" basis assumes moisture transfer among materials in collection and storage, but no net addition or loss of moisture for the aggregate of materials. Based on estimates in: Niessen, W. R., and S. H. Chansky. The nature of refuse. *In* Proceedings; 1970 National Incinerator Conference, Cincinnati, May 17-20, 1970. New York, American Society of Mechanical Engineers. p. 7-8.

Note: Details may not agree with totals due to rounding.

TABLE 2

POST-CONSUMER NET SOLID WASTE DISPOSED OF, BY MATERIAL AND PRODUCT CATEGORIES, 1971-75*

(As-generated wet weight, in millions of tons)

Materials and products	1971	1972	1973	1974	1975
Material composition:					
Paper	39.1	42.5	44.2	43.4	37.2
Glass	12.0	12.7	13.2	12.9	13.3
Metal	11.8	12.1	12.4	13.0	12.2
Ferrous	(10.6)	(10.8)	(11.0)	(11.5)	(10.8)
Aluminum	(0.8)	(0.9)	(1.0)	(1.0)	(0.9)
Other	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)
Plastics	4.2	4.7	5.0	4.5	4.4
Rubber and leather	3.3	3.4	3.6	4.1	3.3
Textiles	1.8	1.8	1.9	2.1	2.1
Wood	4.6	4.7	4.9	4.8	4.9
Total nonfood product waste	76.9	82.0	85.3	84.8	77.5
Food waste	22.0	22.2	22.4	22.6	22.8
Total product waste	98.9	104.2	107.7	107.4	100.3
Yard waste	24.1	24.5	25.0	25.5	26.0
Miscellaneous inorganics	1.8	1.8	1.9	1.9	1.9
Total	124.8	130.5	134.6	134.8	128.2
Product composition:					
Newspapers, books, magazines	10.3	10.9	11.3	11.5	9.8
Containers and packaging	41.7	45.1	46.8	45.4	41.7
Major household appliances	2.1	2.1	2.1	2.1	2.3
Furniture and furnishings	3.2	3.3	3.4	3.3	3.4
Clothing and footwear	1.2	1.2	1.3	1.3	1.3
Other products	18.4	19.5	20.4	21.1	18.9
Total nonfood product waste	76.9	82.0	85.3	84.8	77.5
Food waste	22.0	22.2	22.4	22.6	22.8
Total product waste	98.9	104.2	107.7	107.4	100.3
Add: Yard and misc. organics	25.9	26.3	26.9	27.4	27.9
Total	124.8	130.5	134.6	134.8	128.2

*Office of Solid Waste, Resource Recovery Division, and Franklin Associates, Ltd. Revised February 1977. Details may not add to totals due to rounding.

paperboard (and associated waste generation) did not decrease to nearly the extent implied by the mill production and shipments figures which constitute the primary data for EPA's material flows estimates of solid waste. Unfortunately, there is insufficient information for making corrective adjustments at this time. Therefore, users of the data for 1975 should understand that the paper and board waste generation figures, especially in the packaging categories, are considered to understate the true waste generation results for that year. By the same reasoning, the 1975 decreases in total waste and in the total container and packaging category shown in Table 2 are also to some extent overstated.

Other selected packaging categories, including steel, aluminum and plastics, also decreased and many other nondurable product wastes were in a no-growth situation during 1975. The decline in steel beverage container consumption, however, is attributed largely to a loss in markets to competing glass bottles and aluminum cans, both of which showed increases in 1975 compared to 1974.

The actual decrease in product waste generation for 1975 does not signal a general leveling off or long-term decline in U.S. solid waste generation. As the analysis of product category trends indicated, the major tonnage decrease was concentrated in paper packaging, and the behavior of these materials over the years as a business cycle barometer is well known. In fact, it is expected that the final data for 1976 will show an equally dramatic rise in paper and paperboard packaging, reflecting industrial recovery and increased purchasing following the low point of the business recession during the first half of 1975.[6,7]

Although fuel prices have increased greatly in the recent past, there is no indication that underlying longer-term economic growth forces have changed significantly since the 1960's or early 1970's. Thus, barring unexpected worldwide shortages of major raw materials or major waste reduction policy actions by Congress, waste generation rates should rebound in 1976 and 1977 to the rising trend of the early 1970's.

RECOVERY OF MATERIALS AND ENERGY, 1971-75

Ideally, it would be useful to have detailed statistical time-series data for material and energy recovery from post-consumer waste on a material-by-material, grade-by-grade, product-by-product basis. This would enable tracing the flows from specific waste sources and recovery techniques to specific end-use markets. For the most part, detailed data of this type does not exist and is not likely to become available in the foreseeable future. The waste sources are so numerous, the recovery and processing activities so diverse, and the end-use markets so complex that the data-gathering tasks would pose formidable, although not insoluble, problems. EPA has, however, made a start in assembling existing government and industry trade association statistics for purposes of developing some crude estimates of material recovery from the post-consumer municipal waste stream. This section summarizes these estimates.

Material Recovery

Product-source and kind-of-material details for 1975 post-consumer waste are presented in Tables 3 and 4, indicating gross discards before recycling, quantities recycled, and net waste residual after deducting amounts recycled. As in Tables 1 and 2, net disposal includes litter as well as collected and uncollected waste destined for incineration, landfills, and dumping. Since the post-consumer waste generation and recycling definitions used here exclude industrial fabricating and converting waste sources and a number of special obsolete scrap sources (such as demolition debris and junk autos), the recycling estimates in Tables 3 and 4 do not correspond closely to other published recycling estimates. The latter, such as those published by the U.S. Bureau of Mines and the U.S. Department of Commerce, usually report much larger quantities of material recycled because they include material recovered from some or all of these other scrap sources.

It is evident that overall recovery is not great—about 8 million tons per year, or 6 percent of gross municipal discards. It is also obvious that wastepaper recycling dominates the recovery statistics, comprising about 88 percent of total recovered tonnage and achieving a recovery rate of over 15 percent of gross household and commercial wastepaper generation. The only other material currently approaching a significant recovery rate is aluminum cans, where the amount recovered has increased rapidly over the past 4 years as the result of aluminum can recycling programs initiated by the aluminum and brewery industries.

The depressing influence of the recession on 1974-75 secondary materials markets caused material recycling tonnages to decrease slightly during 1975 compared with 1971-74 (Table 5). In percentage terms, the overall recycling rate with respect to gross discards decreased to 5.9 percent from 6.5 percent the previous year.

Table 6 provides a time profile of recycling for 1971-75 for individual materials consistent with Table 4 material categories. The recovery rates would seem to be on a slight upward trend if the recession impact of 1975 were discounted. The rates for aluminum, steel, and glass have all risen. It is quite likely that the material recovery picture for steel will be altered significantly over the next few years as some of the larger mixed-waste processing plants with magnetic separation units go into operation (see Chapter 5).

Energy Recovery

Although energy recovery from mixed municipal solid waste has not yet become quantitatively significant in the U.S. resource recovery picture, by the end of 1975, 13 energy recovery facilities were operational (although not necessarily operating). Of these, three (at St. Louis, Missouri; East Bridgewater, Massachusetts; and South Charleston, West Virginia) were pilot or demonstration facilities operated only

TABLE 3

POST-CONSUMER AND COMMERCIAL SOLID WASTE GENERATED AND AMOUNT RECYCLED, BY DETAILED PRODUCT CATEGORY, 1975*

(As-generated wet weight, in thousands of tons)

Product category	Gross discards	Material recycled		Net waste disposed of		
		Quantity	Percent	Quantity	% of total waste	% of nonfood product waste
Durable goods:	14,740	390	3	14,350	11	19
Major appliances	2,430	150	6	2,280	2	3
Furniture, furnishings	3,370	0	0	3,370	3	4
Rubber tires	1,790	190	11	1,600	1	2
Miscellaneous durables	7,150	50	1	7,100	5	9
Nondurable goods, exc. food:	24,140	2,775	11	21,365	17	27
Newspapers	8,850	1,820	21	7,020	5	9
Books, magazines	3,075	255	8	2,820	2	3
Office paper	5,210	700	13	4,510	4	6
Tissue paper, incl. towels	2,235	0	0	2,235	2	3
Paper plates, cups	485	0	0	485	–	–
Other nonpackaging paper	1,045	0	0	1,045	1	1
Clothing, footwear	1,250	0	0	1,250	1	2
Other misc. nondurables	1,990	0	0	1,990	2	3
Containers and packaging:	46,550	4,810	10	41,740	33	54
Glass containers:	12,520	370	3	12,150	10	16
Beer, soft-drink	6,345	250	4	6,095	5	8
Wine, liquor	1,790	30	2	1,760	1	2
Food and other	4,385	90	2	4,295	3	6
Steel cans:	5,525	300	5	5,225	4	7
Beer, soft-drink	1,340	65	5	1,275	1	2
Food	3,195	160	5	3,035	2	4
Other nonfood cans	760	40	5	720	1	1
Barrels, drums, pails, misc.	230	10	5	220	–	–
Aluminum:	770	85	11	685	1	1
Beer, soft-drink†	510	80	16	430	–	1
Other cans	25	0	0	25	–	–
Aluminum foil	235	5	2	230	–	–
Paper, paperboard:	23,135	4,055	18	19,080	15	25
Corrugated	12,520	2,755	22	9,745	7	13
Other paperboard	5,470	720	13	4,750	4	6
Paper packaging	5,145	560	11	4,585	4	6
Plastics:	2,635	0	0	2,635	2	3
Plastic containers	420	0	0	420	–	–
Other packaging	2,215	0	0	2,215	2	3
Wood packaging:	1,800	0	0	1,800	1	2
Other misc. packaging	165	0	0	165	–	–
Total nonfood product waste	85,430	7,975	9	77,455	61	100
Add: Food waste	22,785	0	0	22,785	18	29
Yard waste	26,010	0	0	26,010	20	33
Misc. inorganic wastes	1,900	0	0	1,900	1	2
Total	136,125	7,975	6	128,150	100	164

*Office of Solid Waste, Resource Recovery Division, and Franklin Associates, Ltd. Revised January 1977.

†Includes all-aluminum cans and aluminum ends from nonaluminum cans.

TABLE 4

POST-CONSUMER RESIDENTIAL AND COMMERCIAL SOLID WASTE GENERATED AND AMOUNTS RECYCLED, BY TYPE OF MATERIAL, 1975*

(In millions of tons, as-generated wet weight)

Material category	Gross discards	Material recycled		Net waste disposed of		
		Quantity	Percent	Quantity	% of total waste	% of nonfood product waste
Paper	44.1	6.8	15.4	37.2	28.9	47.8
Glass	13.7	0.4	2.9	13.3	10.4	17.1
Metals	12.7	0.6	4.7	12.1	9.7	15.9
Ferrous	(11.3)	(0.5)	(4.4)	(10.8)	(8.6)	(14.3)
Aluminum	(1.0)	(0.1)	(10.0)	(0.9)	(0.7)	(1.2)
Other nonferrous	(0.4)	(0.0)	(0.0)	(0.4)	(0.3)	(0.5)
Plastics	4.4	0.0	0.0	4.4	3.4	5.7
Rubber	2.8	0.2	7.1	2.6	2.0	3.3
Leather	0.7	0.0	0.0	0.7	0.5	0.9
Textiles	2.1	0.0	0.0	2.1	1.6	2.7
Wood	4.8	0.0	0.0	4.8	3.7	6.2
Other	0.1	0.0	0.0	0.1	0.1	0.1
Total nonfood product waste	85.4	8.0	9.3	77.5	60.4	100.0
Food waste	22.8	0.0	0.0	22.8	17.8	29.4
Yard waste	26.0	0.0	0.0	26.0	20.3	33.6
Misc. inorganic wastes	1.9	0.0	0.0	1.9	1.5	2.5
Total	136.1	8.0	5.9	128.2	100.0	165.5

*Office of Solid Waste, Resource Recovery Division, and Franklin Associates, Ltd. Revised January 1977. Details may not add to totals due to rounding.

TABLE 5

TREND IN MATERIAL RECOVERY FROM POST-CONSUMER MUNICIPAL WASTE, 1971-75*

(In millions of tons)

Year	Gross discards	Material recycled		Net waste disposed of
		Quantity	% of discards	
1971	132.9	8.1	6.1	124.8
1972	139.3	8.8	6.2	130.5
1973	144.2	9.6	6.7	134.6
1974	144.1	9.4	6.5	134.8
1975	136.1	8.0	5.9	128.2

*Office of Solid Waste, Resource Recovery Division, and Franklin Associates, Ltd. Revised February 1977. Details may not add to totals due to rounding.

TABLE 6

TRENDS IN MATERIAL RECOVERY FROM POST-CONSUMER MUNICIPAL WASTE, 1971-75, BY TYPE OF MATERIAL*

(In thousands of tons)

Material recycled	1971	1972	1973	1974	1975
Paper and paperboard	7,495	8,075	8,730	8,430	6,830
% of gross paper and board discards	15.9	16.0	16.5	16.3	15.5
Aluminum	20	30	35	52	87
% of gross aluminum discards	2.4	3.2	3.4	5.0	8.7
Ferrous metals†	140	200	300	400	500
% of gross ferrous discards	1.3	1.4	2.4	3.4	4.4
Glass	221	273	306	327	368
% of gross glass discards	1.8	2.1	2.3	2.5	2.7
Rubber (including tires and other)	257	245	219	194	189
% of gross rubber discards	8.9	7.9	6.8	6.1	6.9
Total materials	8,133	8,825	9,590	9,400	7,975
% of gross nonfood product waste	9.5	9.6	10.1	10.0	9.3
% of total post-consumer waste	6.1	6.2	6.7	6.5	5.9

*Office of Solid Waste, Resource Recovery Division, and Franklin Associates, Ltd. Revised February 1977.

†These estimates for ferrous metal recycling are highly inferential and preliminary. There are no regularly collected statistics on this category. EPA estimates are based in part on work by the Resource Technology Corporation for the American Iron and Steel Institute regarding magnetic separation facilities.

part time, and others, such as those at Ames, Iowa, Siloam Springs, Arkansas, and Groveton, New Hampshire, were either in the initial startup phase or are very small units. Others, such as the Chicago (Northwest) and Harrisburg waterwall incinerators, did not have markets for their steam. Only a few units actually operated as on-line energy recovery units for any significant portion of the year during 1975.

Thus, even though comprehensive energy production or sales data have not been gathered on these facilities, it is not likely that the total waste processed for useful energy recovery by all these facilities could have exceeded 300,000 tons in 1975. During 1976, some capacity additions have occurred as well as fuller capacity utilization at many of the earlier facilities. Nevertheless, it is unlikely that municipal waste processed for energy recovery will reach one million tons per year before 1978 or 1979. Implementation of energy recovery facilities is discussed further in Chapter 5.

FUTURE WASTE PROJECTIONS

EPA has not revised its long-term baseline future projections published in last year's *Report to Congress* (reproduced here as Table 7). However, these projections should be reevaluated in the near future. New tools for performing projection analysis of gross generation have been developed by EPA's Office of Research and Development.[8] Although not yet utilized extensively, computerized projection models, utilizing EPA's "SEAS" computer system, have much promise as a means of evaluating alternative future waste generation trend possibilities.

In addition, there is increasing evidence that the baseline projections, developed in 1973-74,[9] tended to overestimate the rate of increase in resource recovery, especially with respect to paper recycling and the implementation of large-scale facilities for processing mixed wastes. The main problem with the projected baseline rate of mixed-waste processing plants is not that fewer cities than expected are

TABLE 7

BASELINE ESTIMATES AND PROJECTIONS OF POST-CONSUMER SOLID WASTE GENERATION, RESOURCE RECOVERY, AND DISPOSAL, 1971 TO 1990*

	Estimated				Projected		
	1971	1973	1974	1975	1980	1985	1990
Total gross discards:							
Million tons per year	133	144	144	136	175	201	225
Pounds per person per day	3.52	3.75	3.70	3.40	4.28	4.67	5.00
Less resources recovered:							
Million tons per year	8	9	9	8	19	35	58
Pounds per person per day	0.21	0.23	0.23	0.20	0.46	0.81	1.29
Equals net waste disposed of:							
Million tons per year	125	135	135	128	156	166	167
Pounds per person per day	3.31	3.52	3.48	3.20	3.81	3.86	3.71

*Office of Solid Waste, Resource Recovery Division. Updates for 1974 and 1975 by Franklin Associates, Ltd.

progressing with plans for implementation, but rather that most plans are featuring plants in the small-to-medium size range (averaging 1,100 tons per day) rather than the larger average sizes assumed in making the baseline projection. Thus, the baseline resource recovery projection portrayed in Table 7, although still not impossible to achieve by 1985 or 1990, now looks more like the high side of a broad range of possibilities rather than the likely midpoint projection. The baseline projections should thus be used with caution. It should also be remembered that they were developed under the assumption of an absence of large-scale Federal policy intervention in the areas of waste reduction, resource recovery subsidies, or other incentive measures.

New EPA projection studies under the Resource Conservation and Recovery Act will be undertaken during 1977-78.

REFERENCES

1. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.
2. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and waste reduction; third report to Congress. Environmental Protection Publication SW-161. Washington, U.S. Government Printing Office, 1975. 96 p.
3. Smith, F. L., Jr. A solid waste estimation procedure; material flows approach. Environmental Protection Publication SW-147. [Washington], U.S. Environmental Protection Agency, May 1975. 56 p.
4. Smith, F. A., Comparative estimates of post-consumer solid waste. Environmental Protection Publication SW-148. [Washington], U.S. Environmental Protection Agency, May 1975. 18 p.
5. Smith, F. A., Quantity and composition of post-consumer solid waste: material flow estimates for 1973 and baseline future projections, *Waste Age*, 7(4): 2, 6-8, 10, Apr. 1976.
6. Paper and paperboard: January–November 1976. *American Paper Institute Monthly Statistical Summary*, 54(11): 1-12, Nov. 1976.
7. Statistical series. *In* Pulp, paper, and board; quarterly industry report. Washington, U.S. Department of Commerce, Bureau of Domestic Commerce, Fall 1976. p. 24-25, 32.
8. International Research and Technology Corporation. Forecasting the composition and weight of household solid wastes using input-output techniques; final report. Washington, U.S. Environmental Protection Agency, 1975. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)
9. Franklin, W. E., et al. [Midwest Research Institute]. Baseline forecasts of resource recovery, 1972 to 1990: final report. Environmental Protection Publication SW-107c. U.S. Environmental Protection Agency, 1975. 386 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-245 924.)

Chapter 3

WASTE REDUCTION

Reduction in the rate of waste generation has become a basic goal of solid waste management. Lower waste generation would help reduce the need for land disposal. It would reduce, or slow the growth of, costs for collection and disposal. Lower waste generation also means less material and energy used in production and a lessening of the environmental impacts that result from the entire cycle of resource use, from extraction of raw materials to disposal of wastes.

Waste reduction was defined in the *Third Report to Congress* as prevention of waste at its source by redesigning products or changing the patterns of production and consumption. Waste reduction can be achieved by various means:

- The development and use of products requiring less material per unit of product (for example, smaller automobiles, thinner-walled containers)
- The development and use of products with longer lifetimes, to reduce discards and replacement needs (for example, longer-lived appliances, more durable tires)
- The substitution of reusable products for single-use "disposable" products, and an increase in the number of times that items are reused (for example, reusable plates and cutlery, refillable beverage containers)
- A reduction in the number of units of the product consumed per household per year (for example, fewer automobiles per family)

All of these methods of waste reduction are either being studied or implemented by government agencies and the private sector. This chapter should not be viewed as a comprehensive state-of-the-art review of waste reduction but rather as a summary of the more significant recent developments since the *Third Report to Congress*. This summary includes results of newly available studies; new and proposed Federal legislation; and waste reduction measures at Federal, State, and local government levels and in the private sector.

ACTIVITIES AT THE FEDERAL LEVEL

Guidelines for Beverage Containers

Section 209 of the Solid Waste Disposal Act as amended in 1970 (Public Laws 89-272 and 91-512) required the Administrator of EPA to "recommend to appropriate agencies and publish in the *Federal Register* guidelines for solid waste recovery, collection, separation, and disposal systems . . . ." Section 1008 of the Resource Conservation and Recovery Act of 1976 (P.L. 94-580), which further amended the Solid Waste Disposal Act, continued the Agency's guideline-writing authority. The Act and Executive Order 11752 mandate that Federal agencies comply with these guidelines on Federal facilities. In addition, they are recommended for adoption by State and local governments and private agencies.

Several guidelines have now been issued, including the Guidelines for Beverage Containers, which appeared in the *Federal Register* on September 21, 1976.[1] These are intended to reduce beverage container solid waste and litter, save waste collection and disposal costs to the Federal government, and save energy and materials.

Under the guidelines, a refundable 5-cent deposit will be placed on all containers for beer and soft drinks, including glass bottles which can be refilled and all one-way glass bottles and cans. The deposit is intended to encourage the return of these containers for refilling or recycling.

All Federal agencies must report to EPA by December 1977 on how they will comply with the guidelines. EPA is now working with agencies to develop report forms.

Individual facilities (or groups of facilities) do not have to implement the guidelines if the cost is excessive. Also, if the deposit system does not result in a reasonable rate of return of containers, the system does not have to be continued. Federal agencies that do not choose to install a deposit system at a facility must submit a report to EPA giving details of their decision. The report must contain technical data, market studies, and policy considerations used to make the decision.

EPA estimates that the U.S. Department of Defense (DOD) accounts for 90 to 95 percent of beer and soft drink sales on Federal facilities: DOD, with assistance from EPA, plans to test the guidelines at 10 military bases chosen to represent the total of about 300 bases. The test will guide the DOD decision on how to comply with the requirements of the guidelines.

Legislation Addressing Waste Reduction

In October 1976, the Resource Conservation and Recovery Act (P.L. 94-580) was signed into law, amending the Solid Waste Disposal Act. The law contains provisions for "resource conservation," which is defined in the law as including "reduction of the amounts of solid waste that are generated and reduction of overall resource consumption." Specifically:

- The Act requires guidelines for solid waste management, which is defined to include resource conservation.
- Twenty percent of the appropriation for general administration of the act must be used to support "Resource Recovery and Conservation Panels"–technical assistance teams–to work with State and local governments upon request.
- State plans to be developed and implemented under the act shall include consideration of appropriate resource conservation systems.
- State and local governments are eligible for financial assistance to establish solid waste programs, which may include resource conservation.
- A Resource Conservation Committee, representing seven Federal agencies, is established to conduct a "full and complete investigation and study of all aspects of the economic, social, and environmental consequences of resource conservation." The study is to be completed by October 1978.

During Congressional debate of the bill, an amendment to require refundable deposits nationwide on all beer and soft-drink containers was introduced on the floor of the Senate. This amendment was defeated by a vote of 60 to 26.

In the Energy Policy and Conservation Act (P.L. 94-163), Congress has for the first time required actions by the private sector which will result in significant reductions in the weight of a product often considered as a solid waste: discarded automobiles. The law requires improvements in the average fuel economy of automobiles: the standard for the 1977 model year is 18.6 miles per gallon, and the standard rises each year. For the 1985 model year, the standard is 27.5 miles per gallon. The many changes that will take place to meet these requirements will include reductions in size and weight of cars. This means less use of materials and energy to make new cars, and less material wasted when cars are discarded and not recycled.

Other pieces of legislation relating to waste reduction were introduced into the 94th Congress but not enacted:

(1) Prohibition of the sale of one-way beverage containers on Federal lands (e.g., S. 2833)
(2) The development of Federal packaging guidelines and model standards or regulations for possible adoption by States (e.g., S. 1474)
(3) Federal regulation of oversized and excessive packaging (e.g., H.R. 11393)
(4) The development of product reports and national product standards to reduce the use of energy and materials in short supply (e.g., S. 1744)
(5) The requirement that products be labeled to show expected useful life or durability (e.g., H.R. 876 and H.R. 5540)

Recent EPA Research and Current Studies

Since publication of the *Third Report to Congress*, final reports on several studies sponsored by EPA's Office of Solid Waste relating to waste reduction have been completed. They provide information that will assist the EPA and others in (1) examining resource use and waste generation associated with specific products and product categories and (2) identifying and evaluating alternative ways in which waste could be reduced.

Research Triangle Institute examined 477 consumer products classified by the Department of Commerce and ranked them by resource requirements (e.g., energy, steel) and by residuals (e.g., industrial solid wastes, water discharges, post-consumer solid wastes).[2]

The study found that passenger cars consistently ranked among the highest for material requirements: metals, glass, rubber and plastics. Food packaging requires significant amounts of steel, aluminum, glass, and paperboard.

Of all consumer purchases, direct spending on fuels and electricity for transportation, heating, and lighting resulted in the highest energy consumption. The manufacture and distribution of cars consumed more energy than any other product. The report confirms that smaller, lighter cars result in significant materials and energy conservation beyond the benefits of reduced fuel consumption.

The study also showed that meats, housing, and women's and children's apparel were products with high energy inputs. Products with high energy inputs are generally associated with the largest quantities of atmospheric emissions. Packaging dominates post-consumer wastes, with beer and soft-drink containers the most identifiable packaging products.

The study points out that these 477 consumer products are interrelated. Actions that reduce spending on one product may result in reductions in resource use and residuals associated with that product, but another consequence may be increased spending on another product with equal or greater impact on resources and the environment.

In another contract study, Ernst and Ernst estimated the elasticities of demand for consumer products entering the solid waste stream.[3] Calculations were made of each product's elasticity of demand (i.e., the percentage change in quantity purchased relative to a change in the product's price), cross-elasticities (the percentage change in quantity purchased due to a change in the price of a substitute or complementary product), and income elasticity (the percentage change in quantity purchased in response to a change in real income). Accurate knowledge of these elasticities would help in predicting the effects of price changes (perhaps through higher taxes for virgin materials or tax credits for recycled materials) on the quantities of products consumed. This information could be combined with the environmental impact data for the same products (e.g., from the study by Research Triangle Institute) to derive the changes in environmental impacts likely to result from changes in the prices of products. The elasticity estimates also have much broader general applications in evaluating the effects of government policies, market trends, and proposed private industry pricing changes.

Resource Planning Associates completed a study of the implementation and enforcement of existing Federal programs that directly regulate material usage or product quality and characteristics.[4] The effectiveness of each regulatory scheme was assessed. The programs examined were the Food Regulatory Program (Food and Drug Administration), the Meat and Poultry Inspection and Grading Programs (U.S. Department of Agriculture), the Hazardous Substances and Poison Prevention Packaging Programs (Consumer Product Safety Commission), and the Wool Products Labeling Program (Federal Trade Commission). These programs are not themselves intended to promote waste reduction, but knowledge of their experience in regulating consumer products will assist the EPA and others to assess whether it is desirable or possible to regulate products to reduce wastes.

A project carried out within the Office of Solid Waste examined the likely environmental and economic impacts of a national system of deposits on all beer and soft-drink containers. The results of the study are presented in Chapter 6 of this report.

The Midwest Research Institute is in the process of completing a study of the environmental, health, and economic aspects of five milk container systems: refillable glass bottles, refillable plastic bottles, one-way plastic bottles, one-way paperboard cartons, and one-way plastic pouches.[5] The study attempts to display the different impacts of the milk container systems for the same volume of milk: raw materials use, energy use, water use, industrial solid wastes, airborne emissions, water discharges, and post-consumer wastes. The study also considers health and economic factors. The report is scheduled to be completed in the spring of 1977.

The Midwest Research Institute is also conducting a similar study comparing disposable products with their reusable counterparts: paper towels and cloth towels or sponges; paper napkins and cloth napkins; plastic utensils and stainless steel utensils; single-use diapers and cloth diapers; paper and plastic disposable cups and plastic reusable cups; single-use and reusable institutional bedding and linens. The report examines raw materials use, energy use, water use, industrial solid wastes, airborne emissions, water discharges, and post-consumer waste. It also examines sanitation issues relating to these products and summarizes economic considerations. The report is scheduled to be completed in the summer of 1977.

The Municipal Environmental Research Laboratory, a part of EPA's Office of Research and Development, is also sponsoring research on waste reduction.[6] A 2-year study at the University of Oklahoma will attempt to quantify the energy savings possible through waste reduction: reductions in energy used to make products that become waste and in energy used for waste collection and disposal.

Research by Other Federal Agencies

The Federal Energy Administration shares EPA's interest in the likely effects of a nationwide beverage container deposit system. FEA contracted with Research Triangle Institute[7] to study the impacts of a 5-cent refundable deposit on all beer and soft-drink containers: glass bottles which can be refilled and one-way glass bottles and cans. The study estimated the response of the total beverage industry, including retailers, beverage producers and distributors, container manufacturers, and producers of basic steel and aluminum. Three major areas were examined: (1) changes in annual energy consumption; (2) changes in capital investment needs (in terms of fixed plant and equipment); (3) changes in labor requirements (in terms of jobs and earnings). The report first projects energy, capital, and labor requirements of the beverage industry assuming no deposit legislation is passed; these baseline projections are then compared to projections of what might happen as the result of a deposit law. Results are reported for 1982: the report assumes that a law would be implemented in the late 1970's and that by 1982 transitory effects would have dissipated.

A wide range of impacts could result, depending on two key factors: the market share retained by cans and the rates at which cans and bottles are returned. For illustrative purposes, the report focuses on two scenarios judged to be reasonable. A summary of the net energy and economic impacts for these scenarios is given in Table 8.

The beverage production and distribution system is very complex, and packaging has a critical effect on the system. The study took only a limited number of factors into account and cannot be expected to provide a comprehensive description of impacts. Nevertheless, the authors claim that the material presented can provide an important input to an informed decision-making process.

The General Accounting Office is conducting its own internal review of the likely impacts of mandatory deposit legislation nationwide. This review is planned for completion early in 1977.[8]

The National Science Foundation (NSF), under its program of Research Applied to National Needs, solicited proposals in January 1976 for "Decision-Related Research in the Field of Urban Technology." Within the solid waste management category, waste reduction was identified as a topic of high priority, and two studies addressing this topic were subsequently funded.

The first study, conducted by Franklin Associates, Ltd., will examine technical options for waste reduction, with an emphasis on packaging.[9] The objective of the study is to provide government officials with information that could be used in stimulating packaging technology changes that would reduce wastes without resorting to regulation. The second NSF-funded study, by the University of California at Los Angeles, is concerned with extension of product life as a means of waste reduction. Product lifetimes are determined not only by the physical durability "built in" by manufacturers but also by a variety of other factors. The research seeks information to assist government decision-makers in developing cost-effective policies to influence these lifetimes. Researchers will survey consumers to obtain data about their purchase and disposal of selected durable products, ask manufacturers for information about their actions affecting product lifetimes, and examine the nature and extent of second-hand markets.

TABLE 8

ESTIMATES OF THE NET ENERGY AND ECONOMIC IMPACTS OF MANDATORY DEPOSITS BASED ON ILLUSTRATIVE SCENARIOS OF THE BEVERAGE CONTAINER MARKET AND CONTAINER RETURN RATES, 1982*

	1982 baseline value	Scenario 1: Cans produced stay at 1976 level. Growth in container market since 1976 is completely accounted for by refillable bottles. Return rate for all containers, 90 percent.†	Scenario 2: Cans produced drop to half of 1976 level. Refillable bottles gain this loss plus the growth in the market since 1976. Return rate for all containers, 80 percent.†
Beverage consumption rate, 10^9 ounces annually	1,893.5	- 3.6	- 3.5
Container production rate, 10^9 units annually	90.6	- 33.6	- 48.6
Glass containers	18.0	- 12.2	- 1.6
Refillable	2.4	+ 3.4	+ 14.1
Nonrefillable	15.7	- 15.7	- 15.7
Cans	72.5	- 21.3	- 47.0
Steel	42.0	- 12.8	- 27.5
Aluminum	30.5	- 8.4	- 19.5
System energy requirements, 10^{12} Btu annually	383	-168	-144
System capital requirements,‡ 10^6 dollars	7,303	+824	+2,006
System labor requirements:‡			
Net employment, 10^3	369	+118	+117
Jobs gained	–	156	166
Jobs lost	–	38	49
Labor earnings, 10^6 dollars annually	4,080	+879	+936

*Bingham, T. H., et al. [Research Triangle Institute]. Energy and economic impacts of mandatory deposits; executive summary. Washington, Federal Energy Administration, 1976. 15 p. (In preparation.)

†Values in this column represent deviations from baseline trends in first column.

‡Retailers, distributors, beverage manufacturers, can and bottle manufacturers, steel and aluminum manufacturers.

The Office of Technology Assessment (OTA), a Congressional unit, is also interested in extending product life. Its emphasis is on the use of technology to reduce wear and corrosion and thereby improve materials utilization. In January 1976, OTA held a workshop at which various aspects of "wear reduction" were examined, and in July 1976, it solicited proposals to perform an evaluation of technologies to achieve materials conservation.

STATE AND LOCAL GOVERNMENT ACTIVITIES

Beverage Container Legislation

Some State and local governments continue to [illegible] legislation to require mandatory refunds or deposits for beverage containers. Most of the bills or ordinances introduced have resembled the existing law in Oregon, which requires all containers of beer, malt beverages, and carbonated soft drinks to carry a 5-

cent minimum refund value.* The Oregon law also bans the sale of cans with flip-tops or pull-tabs. Oregon also allows a reduced refund value of 2 cents on "certified" or standard containers that can be refilled by more than one manufacturer. This creates an incentive for use of standard refillable bottles.

A few interesting variations on the legislation have been suggested. For example, proposed legislation in Ohio calls for a transition period of 3 years, during which time a 5-cent tax would be levied on one-way bottles and cans only. The proceeds from this tax would be earmarked for the State's Energy Resource Development Agency to use in supporting resource recovery activities.

Legislation requiring mandatory refund values or deposits has been hotly contested, most vocally by the beverage and beverage container industries.[10-13] Most State and local bills or ordinances affecting beverage containers have been stalled in committees during the past year, while supporters and opponents have debated the likely environmental and economic impacts of their passage.

In November 1976, voters in four States decided whether to adopt mandatory refunds or deposits for beverage containers:

	Percent of Voters	
	For deposits	Against deposits
Colorado	33	67
Maine	57	43
Massachusetts	49.6	50.4
Michigan	64	36

Voters in Michigan and Maine approved deposits for beverage containers, thus joining Oregon and Vermont, which already have such laws, while voters in Colorado and Massachusetts rejected deposits.

Oregon. No change in the existing law is currently contemplated, although there was some effort in 1975 to extend its coverage to wine bottles. This effort has not been continued.

Changes in the kinds of beverages sold and the containers used have occurred since the refund system started in Oregon. At the Blitz-Winehard Company, the only local brewery in the State, 90 percent of the containers are refillable bottles and 10 percent are cans. Before the law was passed, 50 percent of the containers used by this company were cans, 20 percent one-way bottles, and 30 percent refillable bottles.[14] The number of nonlocal beers sold in Oregon has decreased from 29 to 9 since the law was passed. Budweiser, a major out-of-State brewery, changed over to the "certified" or standard refillable beer bottle for the Oregon market and found that its bottles were being bought by local and regional brewers rather than collected and shipped back to them in Los Angeles. Budweiser consequently raised the deposit it charges its distributors and returns to them have since increased.[15] Pepsi-Cola, which previously used a mix of containers that was 25 percent cans, 65 percent refillable bottles, and 10 percent one-way glass bottles, has now converted to refillable bottles only. They report a return rate ranging from 93 percent for 26-oz bottles to 97 percent for 16-oz bottles.[16] Coca-Cola, which still sells drinks in refillable glass bottles and one-way bottles and cans, reports a return rate of 90-95 percent for bottles and an 80-85 percent return rate for cans.[17]

South Dakota. A law prohibiting the use of beverage containers that are not "reusable" or "biodegradable" was passed in February 1974 and was to take effect on July 1, 1976. The law has now been changed to permit the use of containers that are "recyclable" (which presumably includes virtually all bottles and cans), and the effective date has been postponed until July 1, 1978.

Vermont. Deposit legislation has been in effect since 1973. The law provides for: a minimum deposit of 5 cents on all beer and soft-drink containers; a handling charge of 20 percent of the deposit to be paid by the manufacturer or distributor to the retailer; a label on each container clearly indicating the amount of the deposit and the name of the State in which the deposit is valid; the ability to establish (by any person) a centralized refund facility away from a retail store; and a penalty of up to $1,000 for violation of the law. A new law, passed in 1975, has expanded the labeling requirements for one-way

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*Technically, the Oregon law requires that a *refund* be given on all containers that are returned; it does not require that a *deposit* be collected when the beverages are sold. Laws in some other States and localities (e.g., Vermont) do explicitly require deposits.

beverage containers while excluding refillable bottles from these requirements. The new law added bans (effective January 1, 1977) on all one-way glass containers, detachable parts of metal cans, and on plastic rings or similar non-biodegradable devices for holding containers together.

Complete data on the effects of the Vermont legislation are not yet available, although certain trends have been reported.[18] According to surveys conducted by the Vermont State Highway Department, the beverage container portion of highway litter decreased by about 67 percent between 1973 and 1974 (a reduction of more than 8,500 littered containers per month). Tax receipt data indicate that sales of beer declined by about 10 percent in the first year of the law, although this may be due to the general economic decline at that time rather than the law. Sales have subsequently risen. Prices of beer and soft drinks have risen since the law, but they have risen throughout New England and the nation. A limited price survey indicates that Vermont consumers pay the same or less for identical beverages in identical containers compared with consumers in neighboring States.[19]

More soft-drink bottlers are now using refillable bottles exclusively (e.g., Coca-Cola, both in Burlington and in Barre). Beer manufacturers also seem to be shifting toward greater use of glass bottles which can be refilled. The return rates have generally been in the 80 to 95 percent range for bottles.

Several soft-drink distributors and beer wholesalers have reported increases in employment to handle and transport returnable bottles. No significant sales or employment decreases have been experienced by container manufacturers, but Vermont is a relatively small market.

Washington, D.C., Metropolitan Area. The Metropolitan Council of Governments for the Washington, D.C., area has adopted as policy the concept of mandatory deposits on beverage containers and has developed a draft ordinance for its members' use. However, the policy does not become binding unless each of the members adopts it individually. At this time, Montgomery County, Maryland, has passed a mandatory deposit ordinance, effective January 1, 1978. Fairfax County, Virginia, on the other hand, has passed an ordinance for which implementation is conditional on passage by the other jurisdictions. In Prince Georges County, Maryland, the County Council indefinitely postponed a vote on a deposit law and a tax on one-way containers. The District of Columbia City Council has voted down a deposit ordinance. Neither the City of Alexandria nor Arlington County in Virginia have yet taken any formal action.

In addition to passing a deposit ordinance, Montgomery County passed a law, now in effect, requiring that the prices of beverages in refillable bottles be posted minus the deposit.

The County also passed a tax on one-way beverage containers which was to be imposed until deposits took effect in January 1978. This tax was overturned in the court on the grounds that the county has no right to impose sales taxes in Maryland. The County Council altered the language of the tax law to avoid this problem, but the court again ruled the law unconstitutional. The County Council has appealed this judgment again, and the case is pending.

Just outside the Washington, D.C., metropolitan area, a mandatory refund ordinance was passed by Loudoun County, Virginia, but was challenged in the Virginia Circuit Court. The judge found the law was unconstitutionally vague and was pre-empted by State alcoholic beverage (beer) laws. The County has filed an appeal to the Virginia Supreme Court, and this appeal is pending.

A similar mandatory deposit ordinance was passed 5 years ago by Howard County, Maryland; it was to be implemented in 1976. The County Council reconsidered this law, and passed a new deposit law with more specific bans on one-way glass bottles, detachable metal tops of cans, and plastic holders for cans. Opponents and proponents of these laws have both submitted petitions for referendum votes in 1978 on portions of this new law.

If both petitions are upheld, they have the effect of submitting the new deposit law to the voters while letting the original deposit law go into effect. There may be a conflict in this, and the County executive may choose not to enforce the original deposit law until the referendum vote in 1978.

Berkeley, California. A mandatory deposit ordinance was passed by the Berkeley City Council in October 1975 but has subsequently been challenged in court by a group representing local liquor and grocery interests. The suit alleges that the law is unconstitutional, that it was adopted without due process, that it is pre-empted by State law, and that it would infringe on the right to engage in commerce without undue restrictions. A preliminary injunction has been issued, which will prevent the law from being implemented until the case is decided, probably in early 1977.

Other Waste Reduction Activities

So far, most of the attention given by States and localities to waste reduction has been focused on beverage container legislation. However, interest has developed in other approaches to waste reduction, particularly in the States of Minnesota and California.

Minnesota. In May 1973 the Minnesota Legislature passed a comprehensive law (Minn. Stat. 116F.06 (1974)) to reduce the amount and types of material which enter the solid waste stream and to encourage the reuse and recycling of materials. Since packaging represents a large part of municipal solid waste, the Minnesota Pollution Control Agency (MPCA) was specifically given authority to review new or revised packages except when such changes involve only color, size, shape, or printing.

Any person, including the packaging user, may submit the package to MPCA for review. With certain exceptions, the MPCA staff has 120 days to approve or prohibit it. Unless MPCA acts within the 120-day time period to prohibit the package under review, it may not thereafter do so. If the MPCA staff determines the package should be prohibited because it constitutes a solid waste problem or because it is inconsistent with State environmental policies, a public hearing must be held. An MPCA prohibition is subject to review by the Minnesota Environmental Quality Council. Finally, any MPCA prohibition of a package, in order to stay in effect, must be reaffirmed and extended by a State law after a period of time.

Following public hearings, meetings with industrial representatives, and both legislative and legal reviews, the MPCA promulgated "Regulations for Packaging Review" (Minn. Reg. SR-1 through SR-6) on December 31, 1974. The regulations set definitions; set criteria to evaluate new or revised packages; specified the types of samples and information needed by the agency to evaluate packages; established a procedure for the review; and established exemptions for some new or revised packages. On May 29, 1975, a group of industries filed suit alleging that the MPCA had exceeded its statutory authority in issuing the regulations, and that the regulations were vague and burdensome, that they were unconstitutional, and that they imposed an unreasonable burden on interstate and foreign commerce. A temporary injunction restraining the MPCA from enforcing the regulations was granted on July 14, 1975. Petition for a permanent invalidation of the statute and regulations was given a court hearing in May 1976. Both sides then prepared post-trial briefs and submitted them in July 1976. In a December 1976 decision, the law and the regulations were upheld by the court.

California. The Nejedly, Z'Berg, Dills Solid Waste Management and Resource Recovery Act passed by the California Legislature in 1972 required the newly established State Solid Waste Management Board to investigate "changes in current product characteristics, and production and packaging practices, which would reduce the amount of solid waste generated at its source." In January 1975, the Board established a Source Reduction and Packaging Policy Committee and assigned to it the task of preparing a background report and recommending methods to reduce solid waste generation. The Committee included representatives from industry, government, and citizen and environmental groups. The committee sent its findings to the board in March 1976. The report contains information about the nature of waste reduction, its objectives, methods of achievement, and a review of the likely impacts of a variety of measures, including product regulations, minimum warranty requirements, mandatory refunds on beverage containers, taxes on packaging, and disposal charges.[20] The committee unanimously endorsed the support of voluntary waste reduction efforts, but were unable to reach unanimity on other measures. The board has accepted the report and has called for its wide distribution; a public hearing may be held.

OTHER BEVERAGE CONTAINER DEPOSIT EXPERIMENTS

The Yosemite Park and Curry Company (sole concessionaire for Yosemite National Park), in collaboration with EPA and the National Park Service, conducted a pilot test of the Guidelines for Beverage Containers[1] within the National Park from May 17, 1976, until September 17, 1976. All beer and soft drinks sold on park grounds were sold in containers which carried a minimum 5-cent refundable deposit. The deposit was charged at all retail outlets and vending machines throughout the park. The containers carried a special mark, and deposits were redeemed at retail outlets and the existing recycling centers. A public information campaign made use of signs and announcements in the park newspaper, the *Yosemite Guide*.

This test was successful and the system is being continued at the park. The return rate was 69 percent throughout the summer. About 25 tons of glass, aluminum, and bimetal containers were recycled. This is more than four times the amount of materials recycled during the previous 9-month voluntary recycling program. Park officials feel beverage container litter declined. Sales did not decline as a result of the deposits. The park concessionaire profited from the deposit system during the test: the revenues from recycling the bottles and cans, which exceeded the low additional out-of-pocket costs, plus about $16,000 of unredeemed deposits provided the concessionaire with a cash surplus for other environmental programs in the park. The park and the concessionaire received favorable publicity for conducting the test.

In 1975, the senate of Cornell University voted a 1-year trial of mandatory deposits for soft drinks in two areas of the campus. The 5-cent deposit can be refunded at several points throughout the campus. At the same time, the price of all beverages sold elsewhere on campus was raised by 5 cents. The proceeds were to be used to offset the costs of operating the deposit system.

In its First Quarter Report on the trial in February 1976, the Cornell Department of Dining Services cited a number of problems, including: insects at the storage areas for returned containers and an increased need for insecticide spraying; not enough storage space for both full and empty containers; increased costs for labor and transport of containers; decreased sales.[21]

The senate executive committee then authorized a group of students, faculty, and administrators to study the situation. In the report, the majority pointed out:[22]

- The program was poorly publicized.
- Plans did not provide adequately for bottle redemption.
- Lower sales probably resulted from the increase in prices for all beverages sold on campus; one bottler charged more per ounce for soda in refillable bottles than for canned soda.
- The program apparently had a favorable environmental impact. Container consumption was lower, saving energy and materials. Few containers were littered.
- Consumers favored the deposit system by 3 to 1.

Despite a minority report which repeated some of the continuing problems cited by the Department of Dining Services, the senate of Cornell voted to continue the program through October 1976 and then reassess the program. The results of this review were generally encouraging, and the senate voted to make the program permanent.

A number of other schools in New York State have instituted or experimented with deposits on beverage containers. These include Wells College, Syracuse University, State University of New York at Binghamton, SUNY at Albany, and Colgate University.[23]

EXAMPLES OF ACTIVITIES IN THE PRIVATE SECTOR

Newsprint Conservation

In the paper industry, as in many other industries, the rising cost of materials has led to increased efforts to find ways of reducing the material requirements of products. The American Paper Institute recently reported that newsprint can be produced with a 5-percent weight reduction; the product has proved satisfactory in performance.[24]

In a related newsprint conservation effort, many newspapers have made, or are planning to make, a change from their traditional eight-column format to a new format of six columns for news and nine columns for advertising. The change reduces an 88-page paper in the old format to 84 pages in the new, without reducing content; this represents a yearly saving in newsprint of about 5 percent. Some of the newspapers changing their format include the *Los Angeles Times*, *Washington Post*, *New York Times*, and others in Baltimore, Boston, Chicago, Cincinnati, Cleveland, Denver, Detroit, Houston, Memphis, Philadelphia, Phoenix, Pittsburgh, and Wilmington.[25,26]

Automobile Weight Reduction

The fuel consumption of an automobile is very dependent on its weight. In 1975, for example, the Datsun B210 with a weight of about 2,250 pounds achieved 27 miles per gallon in EPA's test of city driving; in contrast, a typical U.S. automobile with a weight of 4,500 pounds achieved only 12 miles per gallon under the same conditions. The largest U.S. automobile with a weight of 5,500 pounds had an even higher gas consumption. This comparison suggests that each 100 pounds added to an automobile's weight increases the amount of gas consumed in an average year's driving (10,000 miles) by about 15-17 gallons.[27]

To improve gas mileage, as mandated by the Energy Policy and Conservation Act, U.S. automobile manufacturers are attempting to reduce the weight of their products. For the 1977 model year, General Motors has reduced the length of its traditionally large standard-size vehicles by an average of 1 foot and has decreased the average weight by 700 pounds. The engines in many models are smaller; for example, the 500-cubic-inch Cadillac engine has now been replaced by a standard 425-cubic-inch engine. Lighter materials are being used wherever possible; for example, General Motors has reduced the weight of many of its larger vehicles by substituting lighter wheels and tires, as well as smaller fuel tanks. Chrysler has achieved a weight reduction in the Plymouth by using new high-strength steel frame members, lighter tires, thinner glass, more aluminum in transmission cases, and more plastic in air conditioners. The trend in sales appears to be toward the intermediate or mid-size vehicles. Ford has redesigned its Thunderbird, which in recent years has been standard-size, to an intermediate size. General Motors is expected to introduce a new range of smaller intermediate vehicles next year.[28] These changes will obviously have an impact not only on fuel economy, but also on the amount of waste generated when the automobiles are ultimately scrapped.

REFERENCES

1. U.S. Environmental Protection Agency. Solid waste management guidelines for beverage containers. *Federal Register*, 41(184):41202-41205, Sept. 21, 1976.
2. Bingham, T. H., et al. [Research Triangle Institute]. An analysis of the materials and natural resource requirements and residuals generation of personal consumption expenditure items; final report. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, 1976. (In preparation.)
3. Ernst & Ernst. An investigation of consumer demand elasticities. U.S. Environmental Protection Agency. 3 v. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)
4. Resource Planning Associates. Implementation and enforcement of Federal consumer product regulatory programs; final report. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, 1974. (In preparation.)
5. Welch, R., et al. [Midwest Research Institute]. Resource and environmental profile analysis of five milk container systems, with selected health and economic considerations. U.S. Environmental Protection Agency, 1976. 2 v. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)
6. Schwartz, W. A., C. L. Stumpf, and D. M. Weber, *comps.* Summaries of active extramural research tasks of the Municipal Environmental Research Laboratory—1975. Cincinnati, U.S. Environmental Protection Agency, Office of Research and Development, June 1976. 254 p.
7. Bingham, T. H., et al. [Research Triangle Institute]. Energy and economic impacts of mandatory deposits; executive summary. Washington, Federal Energy Administration, 1976. 15 p. (In preparation.)
8. Personal communication. L. White, General Accounting Office, to W. D. Conn, University of California, Oct. 1976.
9. Personal communication. W. Franklin, Franklin Associates, Ltd., to W. D. Conn, University of California, Oct. 1976.
10. Mitchell, J. G. Keeping America bottled (and canned). *Audubon*, 78(2):106-113, Mar. 1976.
11. Selby, E., and M. Selby. Can this law stop the trashing of America? *Reader's Digest*, 108(647):69-73, Mar. 1976.
12. Selby, E., and M. Selby. The lobby that battles the bottle bills. *Reader's Digest*, 108(649):237-238, 241-242, 245, May 1976.
13. Brandt, R. J. Summary report: Dade County Bottle Ordinance. Miami, Florida International University, FAU-FIU Joint Center for Environmental and Urban Problems, Feb. 1975. 35 p.

14. Personal communication. B. Wessinger, President, Blitz-Weinhard Company, to J. H. Skinner and N. Humber, Office of Solid Waste Management Programs, Jan. 1976.

15. Personal communication. C. Maletis III, Columbia Distributors, to J. H. Skinner and N. Humber, Office of Solid Waste Management Programs, Jan. 1976.

16. Personal communication. F. Gist, Controller, Pepsi-Cola of Portland, to J. H. Skinner and N. Humber, Office of Solid Waste Management Programs, Jan. 1976.

17. Personal communication. W. Trebilcock, General Manager Coca-Cola of Portland, to J. H. Skinner and N. Humber, Office of Solid Waste Management Programs, Jan. 1976.

18. Loube, M. Beverage containers: the Vermont experience. Environmental Protection Publication SW-139. [Washington], U.S. Environmental Protection Agency, 1975. 16 p.

19. [Skinner, J. H.] EPA objects to misleading advertising on the Massachusetts bottle bill. [Washington], U.S. Environmental Protection Agency, Office of Solid Waste, Oct. 4, 1976. 7 p. (Unpublished report.)

20. Conn, W. D., *ed.* Proposed policies for waste reduction in California; a report prepared for the State Solid Waste Management Board by the Source Reduction and Packaging Policy Committee. [Sacramento], California State Solid Waste Management Board, 1976. 88 p.

21. Cornell University, Department of Dining Services. First quarter report to the University Senate on SA-346 non-returnable/non-refillable container prohibition act. Ithaca, Cornell University Senate, [Feb. 19, 1976]. 7 p. (Unpublished report.)

22. Report of Bottle Bill Study Group. Ithaca, Cornell University Senate, 1976. 5 p. (Unpublished report.)

23. Personal communication. P. S. Hudson, New York Public Interest Research Group, Inc., to N. Getnick, Office of Solid Waste Management Programs, July 1976.

24. Personal communication. C. R. Calkins, American Paper Institute, to W. D. Conn, University of California, Apr. 1976.

25. *Post* shifts to new format. *Washington Post*, 90(242): 3, Aug. 3, 1976.

26. The *Times* alters its column format for news and ads. *The New York Times*, 125(43,326):30, Sept. 7, 1976.

27. Pierce, J. R. The fuel consumption of automobiles. *Scientific American*, 232(1):34-44, Jan. 1975.

28. Hood, P. C. Less for the dollar. *National Observer*, 15(40):9, Oct. 2, 1976.

Chapter 4

SOURCE SEPARATION FOR MATERIALS RECOVERY

INTRODUCTION

Source separation is defined as the setting aside of recyclable waste materials at their point of generation for segregated collection and transport to specialized waste processing sites or final manufacturing markets. Transportation can be provided either by the waste generator, by city collection vehicles, by private haulers and scrap dealers, or by voluntary recycling or service organizations.

To one degree or another, a wide variety of waste products from households and commercial establishments are presently recycled in this manner, including glass and metal containers, automobile tires, large household appliances, and waste lubricating oil from auto crankcases. However, of the roughly 9 million tons of materials currently recycled per year from these sources, over 90 percent is comprised of various types of wastepaper and paperboard (Chapter 2).

Based on current practices, it has been estimated that source separation recycling is likely to increase to about 15 million tons by 1985 in the absence of Federal incentive programs.[1] The supply potential for materials recovery through source separation is far greater, however. EPA estimates that source separation techniques could conceivably be used to recover as much as 50 million tons of materials by 1985. For most materials the principal constraint is insufficient industrial demand. The additional 35 million tons would equal about one-fourth of the nonfood product materials entering the solid waste stream in 1985 and consist mostly of paper (primarily waste news, corrugated, white ledger, and computer papers), glass, metal cans, tire rubber, and household appliances.

In order to be economically viable, increased recycling levels will require both expanded industrial markets for the recovered materials and improved techniques for segregation, collection, and processing. This chapter focuses on recent technology and market developments and Federal efforts since the *Third Report to Congress.*

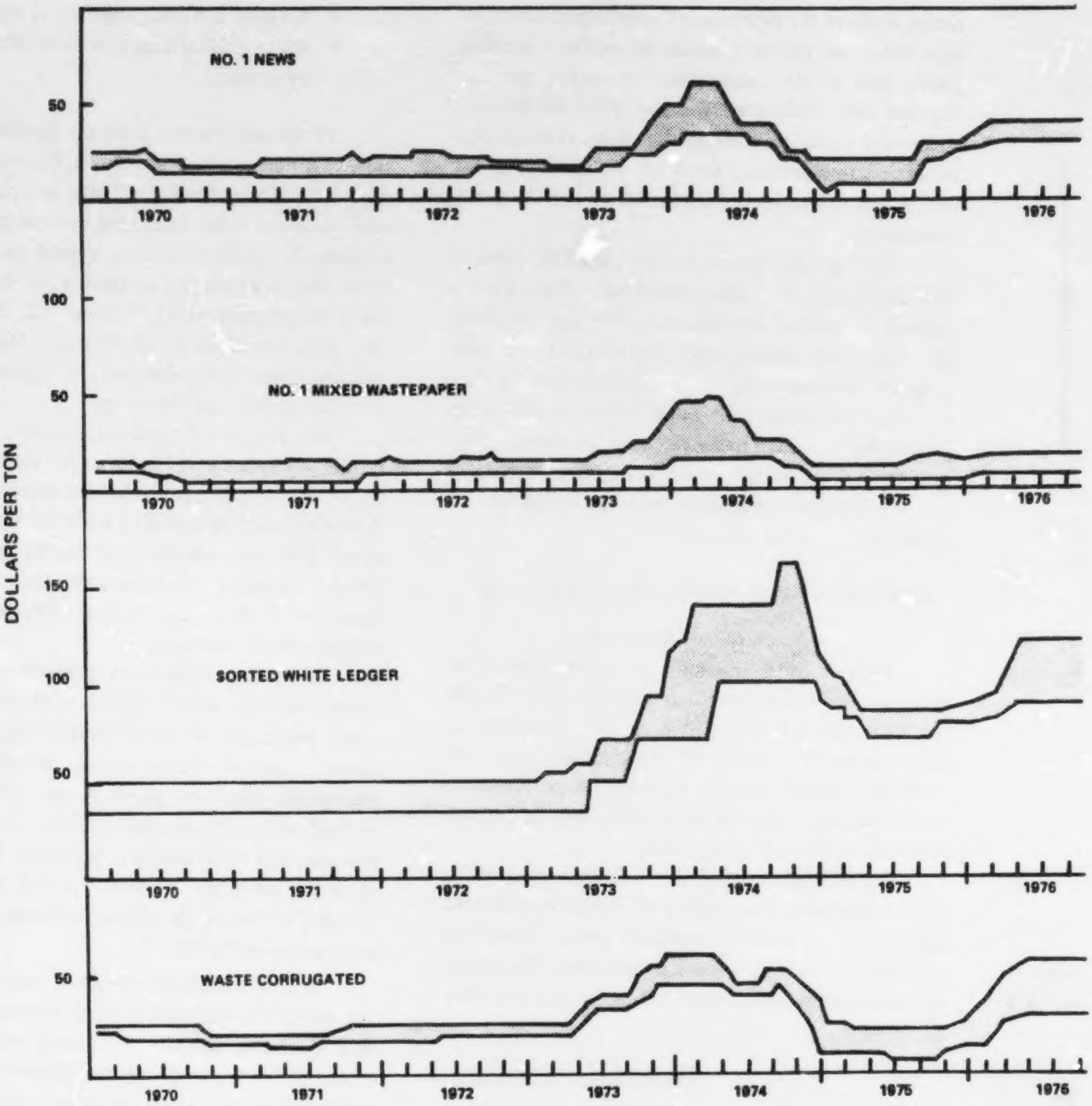
SEPARATE COLLECTION OF OLD NEWSPRINT AND OTHER WASTEPAPER

On the subject of paper, EPA's *Third Report to Congress* focused on the source separation of old newspapers through municipal separate collection. It was reported that the number of known municipal programs for separate curbside collection of used newspapers had grown from 2 in 1968 to 134 in 1974.

The report suggested that the success of municipal curbside newspaper collection programs depended heavily on: the availability of markets within a reasonable distance, active publicity programs to encourage citizen cooperation and participation, careful planning, and "antiscavenger" ordinances to prevent anyone other than the municipal collection crew or private contract hauler from picking up the newspapers placed at the curb.

The *Third Report* also noted that the previously encouraging economic picture which had developed for separate newspaper collection and for the separate collection of corrugated containers from supermarkets and other commercial and industrial sources had been adversely affected by the recession which began in 1974.

More recent data confirm the recession's impact (see graphs). No. 1 waste news prices fell from a high of $38 to $60 per ton in the first half of 1974, to $5 to $25 per ton a few months later. Similarly, waste corrugated prices dropped from their 1973-74 high of $46 to $60 per ton to $8 to $25 per ton in 1975. The recession also adversely affected white ledger and mixed-paper prices. As indicated in Chapter 2 (Table 6), total papermill use of all wastepaper types recovered from post-consumer sources fell by more than 20 percent from 8.7 to 6.8 million tons between 1973 and 1975.



Market prices for wastepaper were subject to extreme fluctuations during the 1973-76 period. Plotted on the graphs are weekly price quotes appearing in *Official Board Markets* for four important wastepaper grades since 1970. The price range presented for each grade reflects the spread of the high weekly quoted prices among four representative market areas: New York, Chicago, Los Angeles, and the South (sic). (Prepared by SCS Engineers and EPA staff.)

The depressed market for wastepaper was the direct result of the recession's severe impact on industries which use products manufactured from recycled paper, such as the construction, packaging, publishing, and other industries. The year 1976 has brought an upward trend in wastepaper markets, as the graphs indicate. Consequently, there are indications of renewed interest in source separation of old news and corrugated.

While precise figures are not available, there is little doubt that the recession adversely affected some existing municipal wastepaper collection programs and may have discouraged the initiation of new programs. However, EPA's best information is that municipal programs that were based on long-term purchasing contracts survived the recession. This underscores the importance of long-term contracts for municipalities planning separate collection of newspapers or other materials.

MULTIMATERIAL SEPARATE COLLECTION

Marblehead and Somerville

Assisted with modest EPA grants, two communities in Massachusetts–Somerville and Marblehead–initiated programs during the past year to demonstrate the extent to which glass, cans, and paper can be economically recovered from the municipal solid waste stream via carefully planned household source separation programs.

Marblehead is an affluent suburban community with a relatively long history of recycling activities. Somerville is a densely populated urban community with no previous experience in recycling. The following data indicate some characteristics of the two communities:

	Marblehead	Somerville
Population	23,000	90,000
Land area	4.5 sq. miles	4 sq. miles
Average annual income	$13,000	$10,000
Average education	College	High school
Recycling history	3 years	None

In Somerville, residents are asked to separate their wastes into three categories:

- All clean paper.
- All glass and cans, together in one container.
- All remaining mixed wastes, which will not be recycled.

In the Marblehead program the glass-can fraction is segregated into two levels, (1) clear glass and cans and (2) brown and green glass and cans. One day each week the paper, glass, and cans are set out at the curbside for collection in a special bucket-loading truck with separate compartments for the paper and the glass-cans mixture(s). In Somerville, the truck has two compartments; in Marblehead, three. The remaining mixed wastes destined for disposal are picked up by a conventional packer truck.

The source-separated materials are taken directly to the purchaser in Marblehead; in Somerville they are taken to a municipal collection center, from which they are periodically hauled away by the buyer. The mixed glass and cans are mechanically separated into ferrous, aluminum, and glass fractions by the purchaser at a processing facility. The wastepaper is shipped directly to users.

The two programs are designed to achieve resource recovery with a minimum of collection costs and a maximum of citizen participation. Local ordinances require source separation. In addition, aggressive public education programs are being conducted to heighten public awareness of the programs and of resource and environmental problems generally, and to make recycling a habit. A full report on the Somerville-Marblehead public awareness program has been published by EPA.[2]

Both communities obtained favorable contracts for sale of the materials through competitive bidding. The contracts specify guaranteed minimum floor prices (Table 9), with escalator clauses tied to current published market prices. In return, the communities assure the contractor a stable supply of materials delivered in a form which can be readily processed into marketable raw materials.

Both cities pay private haulers to collect and dispose of unrecycled wastes. Marblehead pays $18.95 a ton and Somerville $14.50 a ton for disposal services (exclusive of collection). Each ton of wastes recycled is thus a ton that does not have to be disposed of at a cost of $18.95 or $14.50 a ton. With paper, glass, and cans constituting approximately 50 percent of the residential waste stream, source separation and recycling clearly offer both communities significant potential savings in disposal costs.

Somerville began its program on December 1, 1975; Marblehead on January 19, 1976. Preliminary results are encouraging. In Marblehead, revenue from the sales of recovered resources and the savings from reduced waste disposal costs have been consistently producing a net savings of approximately $3,000 a month, despite slightly increased collection costs (Table 10). Somerville has also been realizing savings, although these have fluctuated somewhat thus far (Table 11).

Marblehead, which previously operated a monthly separate collection recycling program, is recovering some 200 tons of paper, glass, and metal each month, or about 25 percent of the total solid waste collected from its 23,000 residents (Table 12). Somerville is recovering about 230 tons each month, or about 8 percent of the total solid waste collected from its 90,000 residents (Table 13).

EPA analysis of similar programs elsewhere indicates that citizen participation in source separation programs rises slowly over time, given a continuing public education program. EPA plans to evaluate the progress of the Marblehead and Somerville demonstrations, including the technical and economic results, throughout the 3-year grant periods. Findings will be reported so other communities can better assess the potential of source separation and the applicability of the Marblehead and Somerville systems to their own areas.

TABLE 9
PRODUCT SELLING PRICES,
MARBLEHEAD AND SOMERVILLE PROJECTS

Material collected	Marblehead		Somerville	
	Guaranteed floor price	Actual prices (1/76 to 10/76)	Guaranteed floor price	Actual prices (12/75 to 10/76)
Paper	$5	$12 to $27	$2	$6 to $21
Glass	12	12	10	10
Cans	10	10 to 16	5	5 to 14

TABLE 10
MARBLEHEAD PROGRAM ECONOMICS,
JANUARY-SEPTEMBER 1976

Month	Revenues from sales	Diverted disposal savings	Incremental collection costs*	Net savings
January (12-31)	$1,870	$2,990	$2,930	$1,930
February	2,560	3,390	3,570	2,380
March	3,790	3,680	4,450	3,020
April	3,500	3,640	4,470	2,670
May	3,400	3,390	3,850	2,940
June	3,730	3,850	4,240	3,340
July	3,280	3,350	4,040	2,590
August	4,340	3,850	4,240	3,950
September	3,360	3,580	4,050	2,890

*Includes labor costs as well as operation, maintenance, and capital amortization for the compartmentalized trucks and all other equipment added as a result of the source separation program.

TABLE 11

SOMERVILLE PROGRAM ECONOMICS, DECEMBER 1975 AND JANUARY–SEPTEMBER 1976

Month	Revenues from sales	Diverted disposal savings	Incremental collection costs	Net savings (costs)
December (1-14)*	$1,240	$2,670	$7,280	$(3,270)
January (12-31)*	720	1,460	3,570	(1,390)
February	2,080	2,890	5,290	(320)
March	3,890	3,260	6,930	220
April	3,350	3,350	6,500	200
May	3,600	3,530	6,200	930
June	4,200	4,290	6,790	1,700
July*	1,460	1,480	2,950	(10)
August	4,270	3,570	6,495	1,340
September	3,180	3,350	6,205	325

*Strikes and snowstorms prevented recyclables collection for 2 weeks in each of these months.

TABLE 12

QUANTITY OF MATERIALS RECOVERED IN MARBLEHEAD, JANUARY–SEPTEMBER 1976

(Tons)

Month	Total residential waste	Recovered materials			
		Paper	Cans and glass	Total	Percent of residential waste*
January (12-31)	475	80	75	155	33
February	560	80	95	175	32
March	690	90	100	190	28
April	720	90	100	190	27
May	795	95	85	180	23
June	890	105	100	205	23
July	755	85	100	185	23
August	880	105	95	200	23
September	730	90	95	185	24

*Though amounts recovered have increased somewhat since the program began, sharp increases in the total waste stream during summer months have resulted in a decline in the percentage recycled.

Other EPA Grants

EPA is also assisting two other separate collection programs with small implementation grants, which were awarded in July 1976.

A grant to Stanislaus County, California, will help the county increase public participation in an existing recycling program operated by a nonprofit corporation which provides free curbside pickup, once a week, of bottles, cans, and newspapers. Objectives include developing collection techniques for apartment complexes, improving existing collection routes, identifying additional markets, and promoting source separation to increase the volume of recovered materials.

San Luis Obispo County, California, has received EPA funding to help implement a source separation program in the city of San Luis Obispo. Later, the program will be applied county-wide. The county is some 200 miles from secondary materials markets, and the program will help determine the feasibility of source separation systems in rural areas distant from markets. The demonstration will also help evaluate the cost-effectiveness of a system using a private hauler.

TABLE 13

QUANTITY OF MATERIALS RECOVERED IN SOMERVILLE, DECEMBER 1975 AND JANUARY–SEPTEMBER 1976

(Tons)

Month	Total residential waste	Recovered materials			
		Paper	Cans and glass	Total	Percent of residential waste†
December*	1,850	130	50	180	10
January*	1,120	60	40	100	9
February	2,430	120	75	195	8
March	2,890	145	75	220	8
April	3,105	145	80	225	7
May	3,260	150	90	240	7
June	3,340	160	130	290	9
July*	1,295	50	50	100	8
August	2,975	135	110	240	8
September	3,085	125	105	230	7

*Strikes and snowstorms prevented recyclables collection for 2 weeks in each of these months.

†Amounts recovered have increased somewhat since the program began, but because the total waste stream increased sharply during summer months, the percentage recycled has remained nearly constant.

Constraints on Multimaterial Programs

The success of multimaterial separation programs such as those at Marblehead and Somerville is based in part on the limited demands on householders in terms of separating and storing the recyclables. By combining glass and cans, it is felt that many more householders can be motivated to participate, and tonnages recovered can be significantly increased. At the present time, however, only one company in New England has installed the relatively simple screening and crushing equipment necessary to process these segregated materials into their individual components. The lack of this intermediate processing capacity in other areas of the country may limit implementation. As an alternative, communities may opt to perform their own processing and ship directly to industrial users of the materials.

While the compartmentalized vehicle in use in Marblehead and Somerville appears to function well, more work is needed in adapting vehicles for separate collection.

MULTIMATERIAL RECOVERY THROUGH RECYCLING CENTERS

Recycling centers have been in existence at least since 1968. Thousands have been established across the country for varying periods of time. In rural and other areas where solid wastes are not collected, recycling centers make possible the recovery of materials which would otherwise be lost.

Nottingham, New Hampshire

In the small town of Nottingham, New Hampshire, source separation and recycling have become a way of life for the 1,200 residents, replacing open dump burning.

By town ordinance, Nottingham residents are required to separate their trash by category: newspaper, corrugated and clean mixed paper, glass, metal, and rubbish. Residents take their wastes to the town recycling center or hire a private collector to do so. At the center, glass is manually sorted by color and then crushed. Aluminum and ferrous cans are magnetically separated and then crushed. Newspaper, corrugated, and flat paper are baled. The recovered materials are then shipped to buyers. Rubbish is burned in an environmentally approved incinerator and the ash put in a landfill.

A survey of Nottingham residents revealed that 80 percent of those using the system supported it.[3] Only 25 percent cited difficulties with home separation, and half of those still favored the system.

The Nottingham system is recovering about 50 percent of the waste delivered to the disposal facility.

The initial investment by the community was $33,295. Although initial reports have been optimistic concerning costs and benefits, EPA has not yet evaluated the results of this project. If it proves economically viable, the Nottingham system could be quite significant for the future of recycling in rural communities.

EPA Grants

EPA recently awarded implementation grants to assist recycling center programs in two other communities.

A grant to Duluth, Minnesota, will help the city establish 12 neighborhood collection stations in shopping centers, from which the source separated materials will be transferred to an existing community recycling center. There, physically and mentally handicapped persons are employed to process paper, metal, and glass for sale to secondary materials users.

A grant to Nez Perce County, Idaho, will help expand and improve three recycling programs already in operation into a county-wide system based on source separation and satellite collection of paper, glass, and cans.

OFFICE PAPER SEPARATION

Last year's *Report to Congress* noted that separation of high-grade office paper was the most significant new development in source separation and was growing rapidly. At that time EPA estimated that some 300 U.S. companies had started programs to separate high-grade wastepaper generated in their office buildings. Termed "white ledger" in the wastepaper trade, this category includes letterhead, dry copy paper, business forms, stationery, typing paper, tablet sheets, and computer tab cards and printout paper.

One paper recycling company recently reported that in 1976, 450 customer organizations were participating in its desk-top office paper collection program, 60 percent more than in 1975.[4] This company is now collecting some 10,000 tons of high-grade paper a year, 72 percent from private businesses, the remainder from State and Federal office buildings. The firm forecasts its tonnage will increase 60 percent this year.

Several other paper companies, both large and small, are developing similar programs with their customers, and although no hard figures are available, the total number of office paper separation programs may now be well over 500.

The most effective system in use is the desk-top program, in which office employees place all high-grade white wastepaper in trays or holders on their desks. When the small desk-top container is filled, the employee empties it into a larger container nearby. The larger containers are emptied periodically, and the paper is taken to a central storage or baling area in the building, from which it is periodically transported by the buyer. Computer tab cards are usually boxed at the computer center in the office building.

The economics of office paper separation programs vary depending upon the size of the office building, the volume of high-grade paper collected, and the structure of the building and its facilities.

EPA studies of six buildings have provided data on the composition of solid waste from office buildings. Waste from the EPA headquarters office (Table 14) was typical of general-purpose office buildings studied. White ledger wastepaper and computer papers represent over 50 percent of the waste stream. In banks and insurance companies, these categories made up over 75 percent of all waste.

TABLE 14
COMPOSITION OF EPA HEADQUARTERS OFFICE WASTE

Type of waste	Lb/day	Percent
Paper:		
White ledger	1,392	40.2
Computer tab cards	25	0.7
Computer printout	367	10.6
Colored ledger	113	3.3
Newsprint	432	12.5
Corrugated	193	5.6
Books/cardboard files	154	4.5
Other	309	8.9
Garbage	113	3.3
Metals	52	1.5
Glass	125	3.6
Textiles	4	0.1
Plastics	34	1.0
Wood	16	0.5
Other	131	3.8
Total	3,460	100.1

A recent EPA contract study of 12 private office paper separation programs reached these conclusions:[5]

- Source separation of office paper can divert substantial portions of office building solid wastes from disposal. Amounts diverted for recycling averaged 34 percent by weight in the 12 programs studied; one building's solid waste load destined for disposal was reduced 78 percent (Table 15).
- Source separation of wastepaper is practicable and economically sound in office buildings. Overall, net solid waste management costs were reduced an average of 12 percent (Table 16).
- Cost-effectiveness is highest in programs source-separating white high-grade paper exclusively.
- Startup costs are not excessive but generally require some expenditures for initial publicity and education, equipment, and to a lesser extent, labor.
- Employees respond favorably. Voluntary participation in the programs studied averaged 80 percent; in some programs, it was as high as 95 percent.
- Publicity and education are essential at the outset and thereafter to encourage participation and to minimize contamination of the paper to be recycled.

EPA analysis of desk-top source separation programs at several Federal facilities confirms the effectiveness of this method. For example:

The National Bureau of Standards facility in Boulder, Colorado, with 1,400 employees, began its program in 1974. The facility generates about 25 tons of waste each month. Of that total, 7.8 tons of high-grade paper are being recovered each month, or about 32 percent. The government is receiving about $60 per ton for the paper.

EPA headquarters in Washington, D.C., with 2,750 employees, began its program in 1975. The headquarters generates some 38 tons of waste each month. Of that total, 15 tons of high-grade paper are being recovered each month, or about 40 percent. The government is currently receiving $70 per ton for the paper, or $12,600 a year.

Analysis of desk-top source separation programs in operation indicates that programs of this type should reduce solid waste management costs an average of 21 percent, reduce waste volume an average of 39 percent, and achieve a 90 percent participation rate, with minimum incremental labor costs to collect the source-separated paper. Contamination levels averaged 3 percent in the case studies and so were well within the 5 percent range allowed by manufacturers.

In sum, it appears that office separation of wastepaper for recycling is increasing as private companies, universities, government agencies at all levels, and other institutions which generate significant amounts of wastepaper learn that it makes sense economically and environmentally, it is a sound business practice, and it generates good public relations. Increasing demand for high-grade wastepaper and increasing costs of solid waste disposal point to a healthy outlook for this segment of the paper recycling industry.

ALUMINUM INDUSTRY RECOVERY OF SOURCE-SEPARATED ALUMINUM CANS

According to the Aluminum Association, a record 3.9 billion all-aluminum cans were returned for recycling in 1975—approximately one out of four cans sold; this was 70 percent more than in 1974.[6] The 87,000 tons of cans amounted to 7.8 percent of the estimated total of 1.1 million tons of "old scrap" aluminum recycled from all sources in 1975. Most of the aluminum was from junked transportation equipment (including autos) and various demolition wastes.

The industry opened its first can collection center in 1967; there are now approximately 1,300 centers. The industry attributes the growth in aluminum can recycling to one fundamental motive: profit. The industry currently pays $300 a ton for aluminum cans and is buying all the cans it can obtain. A major reason is the industry's desire to reduce energy costs: recycling used aluminum requires less than 5 percent of the energy needed to produce aluminum from ore.

TABLE 15

PERCENT OF TOTAL WASTE DIVERTED FROM DISPOSAL AS RESULT OF SOURCE SEPARATION, BY BUILDING TYPE, METHOD OF SEPARATION, AND PAPER GRADE*

Building type/number	Percent diverted from disposal	Method/building number	Percent diverted from disposal	Paper grade/building number	Percent diverted from disposal
Bank/Insurance:		Desk top:		White only:[†]	
1	73	3	78	3	78
2	19	5	29	5	29
3	78	10	7	10	7
4	70	Average	38	Average	38
Average	60	Dual basket:		White, colored:[‡]	
General office:		7	17	2	19
5	29	8	28	6	42
6	42	11	9	12	18
7	17	Average	18	Average	26
8	28	Central container:		White, colored, mixed:[§]	
9	17	1	73	1	73
Average	27	2	19	4	70
Multipurpose		4	70	Average	72
10	7	6	42	Mixed only	
11	9	9	17	7	17
12	18	12	18	8	28
Average	11	Average	40	9	17
				11	9
				Average	18
Overall average	34	Overall average	34	Overall average	34

*Categorical averages may not be conclusive due to limited number of case studies and multiple independent variables.

[†] Computer tab cards, printout, and ledger.

[‡] Ledger.

[§] Multigrade.

TABLE 16

IMPACT OF SOURCE SEPARATION ON OVERALL OFFICE BUILDING SOLID WASTE MANAGEMENT COSTS, BY TYPE OF BUILDING*

	Solid waste management cost ($/ton)		Incremental cost factors (% change[†])						
Building type/number	Prior to source separation	After source separation	Net effect	=	Collection[‡]	+	Disposal	+	Revenue
Bank/Insurance:									
1	34	23	-32		+ 1		- 7		-26
2	61	64	+ 5		+23		- 6		-12
3	92	60	-35		+12		0		-47
4	53	38	-28		+46		-15		-59
Average change	–	–	22		+21		- 7		-36
General office:									
5	107	80	-25		+ 2		- 5		-22
6	315	294	- 7		+ 1		- 4		- 4
7	74	67	- 9		0		0		- 9
8	412	419	+ 2		+ 6		- 2		- 2
9	77	70	- 9		+ 5		-12		- 2
Average change	–	–	-10		+ 2		- 4		- 8
Multipurpose:									
10	47	43	- 8		+ 4		0		-12
11	75	80	+ 7		+12		0		- 5
12	134	132	- 1		+ 8		0		- 9
Average change	–	–	- 1		+ 8		0		- 9
Overall average change	–	–	-12		+10		- 4		-18

*Categorical averages may not be conclusive due to limited number of case studies and multiple independent variables.

[†] Change as a percent of total solid waste management cost (per ton) prior to implementation of source separation.

[‡] "Collection" encompasses equipment and/or labor to store, collect, and/or process source-separated paper.

FEDERAL ACTIVITIES

EPA Guidelines on Source Separation

On April 23, 1976, EPA issued guidelines for the source separation of residential, commercial, and institutional solid wastes, under the authority of Section 209(a) of the Solid Waste Disposal Act, as amended by the Resource Recovery Act of 1970.[7]

The guidelines are mandatory for Federal agencies which generate economically recoverable paper wastes; they also serve as recommended or suggested practices for State, interstate, and local governments, as well as private organizations desiring to increase resource recovery.

The guidelines require source separation and recycling of high-grade paper in Federal office buildings employing 100 or more people, recycling of newspapers from Federal facilities (such as military installations) housing 500 or more families, and recycling of corrugated containers from Federal facilities generating 10 or more tons per month.

High-Grade Office Paper. The major impact of the guidelines will be to increase recycling of high-grade office wastepaper. The guidelines became effective as of May 24, 1976, and should begin to produce results in about 1 year. When fully implemented, the guidelines will return to the paper industry for reuse an estimated 220,000 tons of high-grade paper fiber each year.

Estimated savings to the Federal government will be $7.4 million a year–$2 million a year at the 2,291 owned and 346 leased office buildings managed by the General Services Administration, $2.5 million a year at Department of Defense office facilities, and $2.9 million a year at other Federal office facilities.

The guidelines provide methods, procedures, and techniques for establishing paper separation programs. They are based on the desk-top system already proven at more than 450 private and government office facilities. Table 17 lists Federal facilities currently using the desk-top system.

Waste Corrugated. The guidelines for recovery of waste corrugated containers will apply primarily to military commissaries, which generate some 218,500 tons of corrugated waste a year and which now spend about $6.12 million a year for collection and disposal of the waste. An estimated 95,000 tons of corrugated are expected to be recycled each year. Estimated savings to the government will be approximately $1.38 million per year.

Waste Newspaper. The guidelines for recovery of waste newsprint will apply primarily to military housing areas, which now generate some 32,000 tons of used newspapers each year. An estimated 8,000

TABLE 17

FEDERAL FACILITIES USING THE DESK-TOP SOURCE SEPARATION SYSTEM, 1976

Agency	Location	Date implemented	Number of employees
Bureau of Land Management	Denver, Colo.	10/76	500
Bureau of Mines			
Building #20	Denver, Colo.	8/75	56
Building #53	Denver, Colo.	8/75	195
Bureau of Reclamation	Denver, Colo.	10/74	1,200
Civil Service Commission	Denver, Colo.	2/76	150
Energy Research and Development Agency	Golden, Colo.	3/74	500
Environmental Protection Agency	Denver, Colo.	11/75	265
Environmental Protection Agency	Washington, D.C.	11/75	3,000
General Services Administration	Denver, Colo.	8/75	500
Geological Survey	Denver, Colo.	2/76	400
Mine Enforcement Safety Administration	Denver, Colo.	2/76	100
National Bureau of Standards	Boulder, Colo.	1/74	1,400
National Center of Atmospheric Research	Boulder, Colo.	11/74	500
Tennessee Valley Authority	Chattanooga, Tenn.	1/76	
U.S. Customs House	Denver, Colo.	2/76	300
Federal Building	Denver, Colo.	4/76	3,000

tons of newsprint are expected to be recycled each year, at no additional cost to the government.

Other Products. The guidelines also contain recommended, not mandatory, procedures for Federal agencies to follow for separating glass, cans, and mixed paper waste in areas where markets exist or can be developed for those materials.

Implementation. To help agencies establish office paper recovery programs, EPA is developing a step-by-step implementation manual, based on case studies of successful programs and EPA's own experience with the program.

EPA will also work with the General Services Administration (GSA) to help it establish specifications and secure contracts for the sale of the recovered paper in each Federal region. GSA is responsible for selling all wastepaper generated by Federal civilian recycling programs.

Prototype programs will then be initiated in the major Federal office building in each region and in 10 additional Federal buildings in selected regions by the end of 1977. EPA plans to monitor and evaluate the prototype paper separation and recycling programs as they are implemented and will report the results to those agencies and to others planning to begin the program.

Reactions. The guidelines were first published in the *Federal Register* in proposed form on September 17, 1975, and written comments on the proposed regulations were invited. Comments were received from 90 sources. Of these, 28 favored promulgation without modifications, 35 favored promulgation with modifications that would strengthen the guidelines and reduce flexibility, 5 favored promulgation with modifications that would weaken the requirements placed on agencies, and 1 opposed promulgation. The 21 other comments favored promulgation with minor clarifications and/or procedural changes. Following evaluation of the comments, clarifying revisions were made in the guidelines.

As proposed, the guidelines were strongly supported by citizen organizations, the general public, industry associations, and paper companies. Space does not permit inclusion in this report of lengthy excerpts from the comments, but it is interesting to note reactions to the proposed guidelines from some paper companies.

One company, a major consumer of recyclable materials, wrote:

> We applaud your strong and positive initiative in this important issue. We are convinced that the government will not only find it economically attractive to follow your guidelines, but we call attention to other environmental concerns, such as energy conservation, resource conservation, and reduced solid waste disposal costs, which make the guidelines of critical importance to the nation.

Another paper company wrote:

> Mandatory separation requirements for wastepaper on the part of government agencies will help further to draw national attention to the need to conserve resources, reduce waste disposal and produce high value industrial raw materials. Experience gained by the Federal government, in its efforts to establish effective source separation systems, will be of substantial value to both public and private agencies and organizations which contemplate similar programs.

All of the comments on the proposed regulations and EPA's disposition of them are on file and are available to interested persons at EPA headquarters.

Procurement Requirements for Federal Agencies

Under the Resource Conservation and Recovery Act, enacted October 21, 1976, Federal agencies will be required in procuring products to select those composed of the highest percentage of recycled material practicable. This requirement will apply to procurements after October 21, 1978, and to items purchased in amounts totaling $10,000 or more during the preceding fiscal year. By April 1978 Federal procurement specifications will be reviewed to assure that any exclusion of recovered material is eliminated, that specifications do not require virgin materials, and that specifications require reclaimed materials to the maximum extent practicable without seriously impairing performance characteristics.

The Act also requires EPA, after consultation with other Federal agencies, to issue guidelines on how to comply with the requirements; these guidelines are to include recommended procurement practices and information on the availability and uses of recovered materials and products made from them. Overall implementation of the policy on procurement under the Resource Conservation and Recovery Act is the responsibility of the Office of Procurement Policy of the Executive Office of the President, in cooperation with EPA.

In January 1976, EPA had issued recommended but nonmandatory guidelines on Federal procurement.[8] The guidelines recommended (1) the removal of restrictions that prevent greater use of recycled material in products except where performance standards would not be satisfied; (2) specifications require recycled material to be included in products to the maximum extent practicable; (3) performance criteria for products not be overly restrictive and not arbitrarily exclude recycled material; and (4) the type of recycled material that is most difficult to market, i.e., post-consumer waste, receive the greatest stimulus through procurement specifications.

The Comptroller General of the United States, in a report issued in May 1976, cited the need for more management emphasis by the General Services Administration and the Department of Defense "to further expand the procurement of recycled products."[9]

The General Services Administration has indicated it will develop formal policies, objectives, and guidelines to establish a permanent recycled products procurement program. GSA has also revised its specifications for paper products to allow purchases of more recycled paper. The Department of Defense has indicated that it plans to review its policies concerning the preparation of procurement specifications to determine what changes can be made to further enhance the use of recycled materials.

Although the Federal government is a large single consumer, Federal expenditures are only a small fraction of combined industrial, commercial, and personal expenditures for most product categories. Therefore the direct market creation effect of Federal purchases of waste-based products would probably be small relative to the total national markets. However, as the Comptroller General's report noted, "Federal procurement specifications and procurement practices are widely circulated and duplicated by State and local governments and some industries. Therefore, modification of Federal procurement practices could result in more widespread use of recycled materials in other sectors as well. Moreover, Federal purchasing may well have a significant impact on recycled materials demand in localized markets."

Waste Oil Recovery

EPA, the Energy Research and Development Administration, the Federal Energy Administration, the Department of Defense, and the General Services Administration have all begun programs directed at the conservation of waste lubricating oils. These oils represent a small but significant petroleum resource. Re-refining of the oil for reuse as a lubricant appears to be the most energy-conserving method of the several forms of waste oil utilization. How waste oil is used and disposed of is also of concern from a pollution control standpoint, especially because of the lead content of unprocessed crankcase drainings. Improperly controlled burning can result in unacceptable emissions of lead and other contaminants; poorly controlled use or disposal on land can result in water pollution and contamination of agricultural lands.

The Energy Policy and Conservation Act of 1975 requires the National Bureau of Standards to establish tests to determine equivalency between virgin and re-refined oils, the Federal Trade Commission to establish labeling provisions as to product quality, and the EPA to provide guidance on acceptable disposal options, which will also be incorporated into labeling provisions. The Bureau of Standards will most likely develop its testing plans around the testing program that EPA is carrying out with the Department of Defense. In an EPA field test in San Diego, vehicles of the city public works department have been operated on re-refined lube oil exclusively for over 2 years. ERDA is also doing research on product quality as well as undertaking development of new re-refining technology.

The Federal Energy Administration is developing a program aimed at people who change their own oil. A network of service stations will be utilized to encourage the return of crankcase drainings. FEA also has initiated a model law program to assist States in adopting legislation encouraging the recycling of oil.

The General Services Administration has introduced Federal Property Management Regulations aimed at encouraging Federal facilities to recycle waste oil through either energy recovery or rerefining.

Other Federal Activities

In another effort to increase recovery of resources from waste materials and promote the use of recycled products, the Interagency Committee on Resource Recovery, established by GSA, is investigating ways to increase efficient reuse of materials either by recycling or rehabilitation. The committee addresses problems only within the Federal government and hopes that actions taken by the government can help set an example for the nation. Representatives of GSA, EPA, DOD, and several other Federal agencies serve on the committee.

Finally, several EPA publications issued recently provide technical information designed to encourage source separation for resource recovery. These publications include *Decision-Makers Guide in Solid Waste Management*[10] and *Residential Paper Recovery–A Municipal Implementation Guide.*[11] The paper recovery guide includes sample bid specifications, a sample letter of intent to bid for the purchase of wastepaper, a sample contract, and a sample source separation and separate collection ordinance.

REFERENCES

1. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and waste reduction; third report to Congress. Environmental Protection Publication SW-161. Washington, U.S. Government Printing Office, 1975. 96 p.
2. Resource Planning Associates, Inc. Source separation; the community awareness program in Somerville and Marblehead, Massachusetts. Environmental Protection Publication SW-551. [Washington], U.S. Environmental Protection Agency, Nov. 1976. 81 p.
3. Tichenor, R., E. F. Jansen, Jr., and J. Pickering. Economics of a small rural town recycling system: implications of a case study. Research Report No. 43. Durham, University of New Hampshire, Agricultural Experiment Station, June 1975. p. 32-35.
4. Personal communication. Gene Brantman, Shade Information Systems, Inc., to M. Zeldin.
5. SCS Engineers. Optimization of office paper recovery systems. U.S. Environmental Protection Agency, Office of Solid Waste. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)
6. The growth of aluminum can reclamation. New York, Aluminum Association, May 11, 1976. 3 p. [Press release.]
7. U.S. Environmental Protection Agency. Source separation for materials recovery; guidelines. *Federal Register*, 41(80):16950-16956, Apr. 23, 1976.
8. U.S. Environmental Protection Agency. Guidelines for procurement of products that contain recycled material. *Federal Register*, 41(10): 2356-2363, Jan. 15, 1976.
9. Comptroller General of the United States. Report to the Congress; policies and programs being developed to expand procurement of products containing recycled materials; General Services Administration, Department of Defense. PSAD-76-139. Washington, U.S. General Accounting Office, May 18, 1976. 26 p.
10. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Decisionmakers guide in solid waste management. Environmental Protection Publication SW-500. Washington, U.S. Government Printing Office, 1976. 158 p.
11. Hansen, P. Residential paper recovery; a municipal implementation guide. Environmental Protection Publication SW-155. [Washington], U.S. Environmental Protection Agency, 1975. 26 p.

Chapter 5

MIXED-WASTE PROCESSING FOR MATERIAL AND ENERGY RECOVERY

INTRODUCTION

Resource recovery from mixed municipal refuse involves the centralized processing of collected raw waste to separate out recyclable materials and to convert remaining mixed fractions into useful material or energy forms. Because of the heterogeneous nature of mixed refuse and the economics of recovery, virtually all such systems are designed as multiple-product operations. At minimum, ferrous metal is magnetically extracted for recycling and at least one major commodity is derived from the organic fraction–usually, but not necessarily, a fuel or converted energy product.

Depending on technologies and markets, other inorganic materials selected for recycling besides ferrous metal can include glass cullet (either mixed-color or color-sorted), aluminum, and other, heavier, nonferrous metals. Alternatively, some approaches convert various mixed inorganic fractions thermally into a slag or frit material for use as a construction aggregate or in other building products.

Energy recovery processes available or under development include the direct firing of either raw or shredded waste in heat recovery boilers or waterwall combustion units to produce steam, as well as the mechanical, thermal, or biological processing of waste to produce various intermediate solid, liquid, or gaseous fuel products for on-site use or sale to commercial customers. As an alternative to energy recovery, a variety of other options for utilizing the organic components of solid waste are also in use or under development. These include mechanical processes for separating out paper fiber and plastics for recycling as well as biochemical approaches for converting the organic wastes into compost, animal feed, or chemical industry feedstocks.

As an approach to resource recovery, mixed-waste processing offers several attractive features. In addition to integrating easily into conventional mixed-waste collection and transfer systems, most such systems divert very large fractions of the total waste input, leaving a nonmarketable residual for landfilling of no more than 25 percent by weight, or 10 percent by volume, of the raw waste processed. At the extreme, developers of some high-temperature thermal processes claim to convert all the waste throughput into some form of usable product with positive, or at least nonnegative, market value. Energy recovery or bioconversion may be the only feasible resource recovery possibilities for the food and yard waste fractions, which together can constitute over 30 percent of the wet weight of municipal collections.

Of the many competing and complementary unit processes and full-system recovery concepts, only three processes have been widely used thus far. These include: (1) *waterwall combustion* (extensively employed in Europe; seven operating facilities in the United States and Canada); (2) *composting* (widely practiced in Europe, but numerous U.S. installations have shut down due to poor marketing experience); and (3) *magnetic separation of ferrous scrap* (over 30 U.S. applications reported in use at transfer stations, landfill sites, and mixed-waste processing facilities). In addition, however, a number of mechanical separation technologies (generally referred to as refuse-derived fuel, or RDF, systems), including both wet and dry processes, can be considered at the stage of "commercial demonstration," with a number of units in the 400- to 1,000-ton-per-day category at or nearing completion since September 1975 and many others under construction or contracted for. Other processing technologies–most notably the pyrolysis and bioconversion systems–are either in pilot stage or technology prototype demonstration, and will not, therefore, be fully evaluated as to commercial feasibility for some time to come.

Most of the mixed-waste processing systems under consideration involve relatively complex, capital-intensive technologies. Reported and estimated initial capital investment costs typically range from

$5,000 to $50,000 per ton of daily processing capacity, depending on type of process, plant size, and other factors. High initial capital costs imply long-term investment commitments to keep amortization costs per ton of waste at reasonably low levels. In general, the "high-technology" approach also requires highly sophisticated planning, management, and marketing expertise, together with favorable long-term product market possibilities, in order to reduce financial risks to acceptable levels. These factors, together with significant economies in capital and operating costs for larger sized plants, may restrict most of these systems either to larger cities or regional (e.g., countywide) applications. However, recent developments in the field of factory-assembled, small-scale incinerators with heat recovery components make this conclusion less obvious.

The developmental and demonstration work underway should do much in the next few years to reduce uncertainties regarding technical performance and reliability of many of the proposed systems. However, the principal long-term questions relate more to questions of economic feasibility and the extent to which the new technologies can be made to compete with conventional land disposal methods on the one hand, and virgin material and fossil fuel supply sources on the other.

Thus far, the economics appear favorable for a number of cities and regions, particularly where high disposal cost factors combine with favorable market circumstances. However, the early stage of development and the large number of local cost factors and market price uncertainties make it extremely difficult to generalize on future economic potentials for the nation as a whole. On balance, the impact of the Resource Conservation and Recovery Act of 1976 should tend to improve the relative economics of mixed-waste recovery systems by encouraging the closure of many environmentally unsatisfactory but comparatively low-cost land disposal options.

This chapter reports on the major recent trends and significant developments in mixed-waste processing as an update to previous annual reports in this series. The following sections concentrate on five areas: the nationwide trend in facilities implementation; technology developments in materials recovery; technology developments in energy recovery; institutional developments in financing and in State programs, and a review of current Federal activities. (For more detailed or technically oriented surveys of mixed-waste processing systems and facilities, see references 1-7 at end of this chapter.)

NATIONWIDE FACILITIES IMPLEMENTATION

Scope of EPA Facilities Survey

Since 1974, EPA has conducted periodic surveys of community activity in implementing mixed-waste processing facilities.[5,6] Though somewhat restricted in scope initially, the survey now attempts to include all categories and sizes of facilities designed to process mixed municipal refuse for energy and material recovery, including larger scale pilot, testing, and demonstration units as well as those established as regularly operating components of municipal solid waste systems. The principal exclusions are operations limited to handpicking of materials at transfer stations and disposal sites. Also excluded are small-scale experimental or pilot projects. The survey covers facilities at all phases of project development, from preliminary feasibility studies to on-line operation.

Current Status and Recent Trends

EPA's most recent nationwide survey results (Table 18) cover 118 existing, planned, and potential units; as of mid-1976, there were:

- 21 operational facilities (including pilot and demonstration units as well as on-line operating plants)
- 10 units in various stages of construction or startup or undergoing modifications subsequent to initial startup
- 33 projects in the "advanced planning" category (with requests for proposals issued, design studies underway, and/or construction funding authorized)
- 54 localities at the early stage of having commissioned feasibility studies. (This category excluded many communities which have expressed interest or undertaken informal initial studies.)

Readers are cautioned that the survey summary in Table 18 is not directly comparable to similar listings previously published in EPA's *Nationwide Survey of Resource Recovery Activities* (March 1975) and the *Third Report to Congress* (September 1975). Not only have the definitions of types of facilities to include been substantially broadened for the current

TABLE 18

SUMMARY OF RESOURCE RECOVERY MIXED-WASTE FACILITIES IMPLEMENTATION, SUMMER 1976*

Location†	Type‡	Capacity (tons per day)	Products/markets	Startup date
Operational facilities (21):				
Altoona, Pa.	Compost	200	Humus	1963
Ames, Iowa	RDF	400	RDF, Fe, Al	9/75
Blytheville, Ark.	MCU	50	Steam/process	11/75
Braintree, Mass.	WWC	240	Steam/process	1971
Chicago, Ill. (Southwest)	RWI	1,200	Steam	1963
Chicago, Ill. (Northwest)	WWC	1,600	Steam (no market)	1970
N-E. Bridgewater, Mass.	RDF	160	RDF/utility	1974
D-Franklin, Ohio	Materials recovery	150	Fiber, Fe, glass, Al	1971
Groveton, N. H.	MCU	30	Steam/process	1975
Harrisburg, Pa.	WWC	720	Steam (no market)	1972
Merrick, N. Y.	RWI	600	Electricity	1952
Miami, Fl.	RWI	900	Steam	1956
Nashville, Tenn.	WWC	720	Steam/heating & cooling	7/74
Norfolk, Va.	WWC	360	Steam/Navy base	1967
Oceanside, N. Y.	RWI/WWC	750	Steam	1965/74
Palos Verdes, Calif.	Methane recovery		Gas/utility & Fe	6/75
D-St. Louis, Mo. §	RDF	300	RDF/coal-fired utility	1972
Saugus, Mass.	WWC	1,200	Steam/process	4/76
Siloam Springs, Ark.	MCU	20	Steam	9/75
N-South Charleston, W. Va.	Pyrolysis	200	Gas, Fe	1974
N-Washington, D.C.	RDF	80	RDF, Fe, Al, glass	1974
Facilities under construction (10):				
D-Baltimore, Md.	Pyrolysis	1,000	Steam/heating & cooling Fe, glass	6/75
G-Baltimore County, Md.	RDF	550	RDF, Fe, Al, glass	4/76
Chicago, Ill. (Crawford)	RDF	1,000	RDF/utility	3/77
Hempstead, N. Y.	WRDF/WWC	2,000	Electricity, Fe, Al, glass	NA
Milwaukee, Wis.	RDF	1,000	RDF, corrugated, Fe	1977
D-Mountain View, Calif.	Methane recovery		Gas/utility	6/77
N-New Orleans, La.	RDF¶	650	Nonferrous, Fe, glass, paper	11/76
Portsmouth, Va. (Shipyard)	WWC	160	Steam loop	12/76
D-San Diego County, Calif.	Pyrolysis	200	Liquid fuel/utility	4/77
St. Louis, Mo.	RDF	6,000	RDF/utility, Fe, glass, Al	NA
Communities in advanced planning (33): (RFP issued, design study underway, or construction funding made available)				
Akron, Ohio	WWC	1,000	Steam/heat, cool process	7/78
Albany, N. Y.	RDF	1,200	RDF, Fe	NA
Bridgeport, Conn.	RDF	1,800	RDF, Fe, Al, glass	NA
Central Contra Costa County Sanitation District, Calif.	RDF	1,000	RDF/sludge incinerators	1979
Chemung County, N. Y.	RDF	300	RDF, Fe	NA
Dade County, Fla.	WWC/wet-pulp	3,000	Electricity/utility, Fe	NA
G-Detroit, Mich.	RDF/WWC	3,000	RDF/steam	NA
Hackensack, N. J.	RDF	2,500	Steam/utility	NA
Haverhill, Mass.	WWC	3,000	RDF/utility, Fe	NA

(Continued)

**A Nationwide Survey of Resource Recovery Facilities* (ref. 6), updated.

†D = EPA demonstration grant; G = EPA implementation grant; N = non-EPA pilot or demonstration facility; E = ERDA grant.

‡RDF = refuse-derived fuel; WRDF = wet-pulped refuse-derived fuel; WWC = waterwall combustion; RWI = refractory wall incinerator with waste-heat boiler; MCU = modular combustion unit.

§Plant closed down in 1976.

¶Uses RDF technology, but current plan is to landfill the light fraction because of lack of market.

TABLE 18

SUMMARY OF RESOURCE RECOVERY MIXED-WASTE FACILITIES IMPLEMENTATION, SUMMER 1976 (continued)

Location†	Type‡	Capacity (tons per day)	Products/markets	Startup date
Communities in advanced planning (33): (continued)				
Honolulu, Hawaii	NA	2,000	Utility	NA
Jacksonville, Fla. (Navy base)	MCU	50	Steam, Fe	NA
Key West, Fla. (Navy base)	Compost	50	Humus, Fe	NA
G-Lane County, Oreg.	RDF	750	RDF	NA
G-Lexington-Fayette Urban Cty. Gov't., Ky.	WWC	1,050	Steam, Fe	NA
Mayport, Fla. (Navy base)	RWI	40	Steam	NA
Memphis, Tenn.	WWC/RDF	2,000	NA	NA
Minneapolis-St. Paul, Minn.	WWC	1,200	Steam/papermill	1980
Monroe County, N. Y.	RDF	2,000	RDF, Fe, Al, glass	NA
G-Montgomery County, Ohio	RDF	1,600	RDF	NA
New Haven, Conn.	WWC	1,800	Steam, Fe	NA
North Little Rock, Ark.	MCU	100	Steam	1977
Onondaga County, N. Y.	WWC	1,000	Steam/heat & cool, Fe	NA
Palmer Township, Penn.	RDF	150	Fuel/cement kiln, Fe	NA
E-Pompano Beach, Fla.	Methane recovery	50	Methane	NA
Portland, Oreg.	RDF	200	RDF, Fe	NA
Riverside, Calif.	Pyrolysis	50	Electricity	NA
Salem, Lynn & Beverly, Mass.	NA	750	NA	NA
Seattle, Wash.	Pyrolysis	1,500	Ammonia	NA
Smithtown, N. Y.	Hand sort	1,000	Newspaper, corrugated, Fe	11/77
Sun Valley, Calif.	Methane recovery		Gas/utility	1978
Takoma, Wash.	RDF	NA	Steam	NA
Westchester County, N. Y.	NA	1,300	NA	NA
D-Wilmington, Del.	RDF/sludge	300	RDF, Fe, Al, glass, humus	NA
Communities which have commissioned feasibility studies (54):				
Anchorage, Alaska		500		
Auburn, Maine		200		
Allegheny County, Pa.		2,000		
Babylon, Huntington & Islip, N. Y.		3,000		
Brevard County, Fla.		200		
G-Charlottesville, Va.		NA		
Cowlitz County, Wash.		100		
Columbus, Ohio		NA		
Cuyahoga County, Ohio		1,200		
DeKalb County, Ga.		1,000		
Dubuque, Iowa		500		
District of Columbia (Metro Area COG)		750		
G-Denver, Colo.		1,200		
Dutchess County, N. Y.		700		
Erie County, N. Y.		2,000		
Fairmont, Minn.		150		
Hamilton County, Ohio		1,500		
Lawrence, N. Y.		500		
Lincoln, Neb.		NA		
Lincoln County, Oreg.		NA		
Madison, Wisc.		200		
Marquette, Mich.		NA		
Miami County, Ohio		NA		
G-Middlesex County, N. J.		NA		
Minneapolis (Twin Resco)		NA		
Montgomery County, Md.		1,200		
Morristown, N. J.		NA		
Mt. Vernon, N. Y.		400		

(Continued)

See previous page for footnotes.

TABLE 18

SUMMARY OF RESOURCE RECOVERY MIXED-WASTE FACILITIES IMPLEMENTATION, SUMMER 1976 (concluded)

Location	Capacity (tons per day)
Communities which have commissioned feasibility studies (54): (continued)	
Niagara County, N. Y.	760
G-New York, N. Y. (Arthur Kill)	1,500
Oakland County, Mich.	NA
Orange County, Calif.	1,000
Phoenix, Ariz.	NA
Pasadena, Calif.	200
Peninsula Planning District, Va.	NA
Philadelphia, Pa.	1,600
G-Richmond, Va.	NA
Riverview, Mich.	NA
Rochester, Minn.	NA
St. Cloud, Minn.	NA
Salt Lake County, Utah	750
Scranton, Pa.	NA
S. E. Virginia Planning District	1,500
G-Springfield, Ill.	NA
Springfield, Mo.	1,000
Tallahassee, Fla.	NA
Tampa/St. Petersburg, Fla.	NA
Toledo, Ohio	1,200
Tulsa, Okla.	NA
Tennessee Valley Authority	2,000
Western Berks County, Pa.	250
Western Lake Superior Sanitary District	400
Winnebago County, Ill.	NA
Wyandotte, Mich.	1,000

G = aided by EPA implementation grant.

survey, but in addition our knowledge of community activity has improved over the years.

In order to obtain a more accurate view of recent trends, previous EPA survey listings have been revised on the basis of present definitions and improved information to provide more consistent comparisons with the current data (Table 19). Overall, there are 48 more facilities listed for July 1976 (118) than for July 1974 (70), including 6 more operational units and 3 more under construction.

Operational Units. The most recent EPA survey results indicate that mixed-waste resource recovery installations in operation are substantially greater in number and exist in a wider variety of types than had previously been generally recognized. The 21 operational units listed in Table 18 include seven different types of technologies and design capacities ranging from 30 to 1,600 tons per day. With the exception of the Altoona, Pennsylvania, composting operation and Franklin, Ohio's EPA-supported wet-pulping fiber recovery demonstration, all are either exclusively or primarily in the energy recovery category. Thirteen of these 19 energy recovery units are direct-firing or "incineration" units designed for the mass burning of raw waste. These include three older (1952-63) refractory wall units, seven waterwall units, and three very new, small-scale modular combustion units in the 20- to 50-TPD range. Of the remaining energy recovery units, four are technology demonstrations or pilot/testing facilities, one is the methane recovery from landfill project at Palos Verdes, California, and the last is the new Ames, Iowa, refuse-derived fuel (RDF) facility.

From a technology implementation standpoint, the six additions to the list of operating plants since 1974 are perhaps of greatest significance. Three of

TABLE 19

TREND IN MIXED-WASTE RESOURCE RECOVERY FACILITY IMPLEMENTATIONS*

Facility status	July 1974	January 1975	July 1975	January 1976	July 1976
Operational	15	15	19	19	21
Under construction	7	8	8	10	10
Advanced planning†	23	30	30	29	33
Feasibility studies‡	25	32	37	52	54
Total	70	85	94	110	118

*EPA interview and file data.

†See Table 18 for definition.

‡Prior to 1976, this category included all communities known to EPA which had "expressed interest" whether or not resources had been committed for feasibility studies.

these (at Groveton, New Hampshire, and Blytheville and Siloam Springs, Arkansas) represent the first municipal waste applications of the small-scale/"package" incinerators with heat recovery modules, previously developed for industrial and institutional boiler markets.

Another recent addition in the mass-burning category is the waterwall combustion unit at Saugus, Massachusetts, which began shakedown operations in the spring of 1976 and is the only new waterwall unit since the Nashville plant began operating 2 years ago. It is also among the largest of its kind in this country (1,200 TPD) and is being closely watched as an example of modern design. In all, EPA now counts five municipal waterwall units with current steam customers in operation in this country. (Two other waterwall units, the Chicago (Northwest) facility—the largest waterwall installation in the U.S.—and the Harrisburg facility, have been included in Table 18 because they have steam-generating capacity even though they do not have markets.)

The completion of the Ames, Iowa, RDF (dry-shredding and air classification) unit in the fall of 1975 is a modern landmark in resource recovery history, especially from EPA's standpoint. Not only does it represent the first "commercial" RDF unit designed as an integral component of a municipal solid waste system, but it is also the first application of a major technology aided by the EPA demonstration program.

Finally, the recovery of methane gas from existing municipal landfill sites is being pioneered in an installation completed in 1975 at Palos Verdes, California, and the concept is being further developed in Mountain View, California.

Facilities Under Construction. This category includes 10 facilities presently under construction or in various stages of startup. With the exception of the San Diego pyrolysis, Mountain View methane recovery, and Portsmouth waterwall facilities, they are in the medium-to-large-scale (550 to 3,000 TPD) category. Three of the 10 (San Diego, Mountain View, and Baltimore City) are federally subsidized demonstration projects, the others being financed by State, local, or private obligations to be recovered through product revenues and tipping fees.

By definition, this category represents the current modern technology coming on line over the next few years. Interestingly, 5 of the 10 plants will use some variation of the "fluff-RDF" technology employing dry-shredding and air classification, which was used for the Ames facility and the earlier EPA demonstration at St. Louis. One of these five, being built by Baltimore County, Maryland, is also adopting the full line of technology for materials recovery developed by the U.S. Bureau of Mines.

Another of the plants under construction, at Hempstead, New York, will use the Black-Clawson hydrapulping technology (previously demonstrated at Franklin, Ohio, for fiber recovery) in combination with a waterwall steam boiler and turbo-generator to produce electricity. The only waterwall unit scheduled to burn unprocessed waste is the small plant at the Portsmouth shipyard, although many plants of this type are in earlier design stages. The remaining three are the EPA-supported demonstrations of pyrolysis at San Diego and Baltimore and of methane from landfill at Mountain View.

Communities at the "Advanced Planning" Stage. "Advanced planning"–the stage in which a request for proposals has been issued, an architectural-engineering design study is underway, and/or construction funding is authorized–corresponds to the category designated "committed" in previous EPA reports. The 33 communities in this category–up from 30 in July 1975 and 23 in July 1974–represent facilities that will be coming on line in the 1979-82 period.

The survey data for this group of communities indicates that plants of the 1979-82 vintage will be similar in size to those now under construction or contracted for 1976-78. They will, however, include, according to present plans, a larger group of waterwall combustion units and a substantial number combining RDF separation with waterwall steam generators. There is also a great deal of interest in the smaller modular combustion units ranging in size from 50 to 100 TPD.

Feasibility Studies. Interest in mixed-waste processing facilities and possible future trends are also indicated by the number of communities that have commissioned feasibility studies. Although this category is particularly difficult to monitor, both as a matter of definition and in terms of assuring completeness, we feel that most communities that belong in the category are now included. Many other localities have expressed varying degrees of interest but, according to EPA information, have not yet actually funded substantive feasibility studies.

Such funding at least reflects a degree of serious intent or, viewed another way, a necessary first step. Localities that have not undertaken such studies by 1976 probably cannot be expected to bring plants to completion within the next 3 to 5 years. The EPA survey data indicate a very substantial growth in expressed interest over the past 2 years. Although part of this increase may simply reflect improvement in EPA survey coverage, it should be noted that all but 12 of the 54 communities currently in this category have been added since the summer of 1974.

DEVELOPMENTS IN MATERIAL RECOVERY FROM MIXED WASTE

Overview

Virtually all of the wastepaper, aluminum cans, and glass containers currently recovered from post-consumer wastes are separated at the source and routed via community collection centers or scrap dealers to industrial processors. Numerous communities are now separating ferrous metal from mixed waste by magnetic separation, but the quantities processed have thus far amounted to a very small percentage of the ferrous metal available in the U.S. mixed-waste stream (see Chapter 2).

However, much developmental and demonstration work in mechanical recovery has been conducted in recent years, and, as shown in Table 18, mechanical recovery of at least some materials from mixed waste will be an integral aspect of all modern large-scale resource recovery facilities. The status of mixed-waste processing technology for materials recovery is summarized below.

Material	Status of recovery technology
Paper	Wet process (hydrapulping) demonstrated for low-grade fiber
	Dry processes in developmental stages (demonstrated in Sweden, Germany, and Italy)
Glass	Mechanical processes available for construction-grade aggregate separation
	Mixed-color recovery of container quality glass by froth flotation demonstrated (pilot plant)
	Color-sorted glass cullet recovery in developmental stage (pilot plant)
Ferrous metal	Electromagnetic separation commercially demonstrated and available
Aluminum	Heavy-media process used commercially in auto scrap recovery
	Electrostatic and electromagnetic methods in advanced development
Other nonferrous metals	Developmental stages (pilot plant)
Plastics	Research and experimental stage in U.S.

In general, the equipment used to size-reduce, screen, and separate materials is being adapted primarily from existing technology in the mining, metallurgical, and pulp and paper industries. Although the original technology is often well established, application to the processing of mixed municipal waste often poses major problems. The U.S. Bureau of Mines has long played a direct and leading role in the adaptation and development of these material recovery processes, culminating in its current pilot plant operations at College Park, Maryland. EPA's Office of Research and Development has also sponsored a number of R & D contracts for testing and evaluating size-reduction equipment, fine-grinding techniques, and preprocessing systems for energy recovery. In addition, the National Center for Resource Recovery, Inc. (NCRR), a nonprofit, industry-financed research and consulting organization, has established an equipment testing and evaluation facility ("ETEF") in Washington, D.C. This facility, operated with the cooperation of the District government and partially supported by EPA and ERDA funds, is testing and evaluating many types of full-scale processing equipment, including several air classifiers, an aluminum magnet, froth flotation of glass, and equipment for pelletizing RDF.

In addition to NCRR's "ETEF" facility, the most important new development in material recovery from mixed waste relates to the fact that new full-scale facilities are now beginning to come on stream. The Ames, Iowa, plant (400 TPD), completed in the fall of 1975, is being followed by the Baltimore County plant (550 TPD) and the New Orleans plant (650 TPD). All three of these facilities are scheduled to recover aluminum and other nonferrous metals as well as ferrous metals, and the latter two plants are scheduled to recover glass. The New Orleans facility, the financial success of which is partially guaranteed by NCRR, will feature a dedicated 3-year test and evaluation phase.

With test facilities in operation and with several commercial-size recovery facilities in startup or under construction, there are now new opportunities to evaluate both recovery process technology and the characteristics of recovered materials. Previously, only limited quantities of materials recovered from mixed wastes have been available from pilot plants to potential purchasers. We are now apparently entering the stage of full-scale market testing in actual commercial situations as greater quantities of these recovered materials are used by industrial buyers.

An important related area is the development of quality standards and specifications for recovered products. Establishment of reasonable and relevant product standards is considered by many to be a key to the future commercial development of the mixed-waste processing sector of the recycling industries. Work is being done in this area by the American Society of Testing Materials (ASTM) and the National Bureau of Standards (U.S. Department of Commerce). In addition to participation on ASTM panels, EPA has also provided contractual support to the National Center for Resource Recovery for development of a set of standards and sampling and test procedures for recovered materials.[8]

Such standards and specifications can serve as a temporary planning baseline for both technology and market development. While there may be some shortcomings in these preliminary standards, they represent an important step in the long-term technical and institutional process of achieving broadly accepted industry-wide product standards in this field.

The following briefly reviews the status of specific technologies for materials recovery.

Specific Technologies

Size Reduction and Organics Separation. Glass and metals are usually recovered from mixed wastes after one or more preprocessing steps involving various combinations of size reduction (shredding, milling, flailing, or hydrapulping), screening, and air or liquid cyclone classification of the wastes. In most systems, these are basic processing steps integral to recovery of both material and energy products.

There are now over 30 manufacturers offering shredders commercially. Air classifiers and liquid cyclone classifiers for separating the size-reduced material into light (predominantly organic) and heavy (predominantly glass and metal) components are less well developed, but there are now at least 10 companies competing for the market.

Until recently, virtually all of this technology was developmental and untested insofar as continuous, large-scale operation is concerned. Now, extensive full-scale testing and evaluation programs are either underway or scheduled to start soon at both test (demonstration) and commercial facilities. In addition to the Bureau of Mines, both EPA and the National Center for Resource Recovery are involved in testing and evaluating the design and performance of size-reduction and air classification equipment. All three organizations have separate but complementary evaluation programs continuing, with EPA's program being primarily based on contracts rather than its own pilot and test facilities. Thus, the next 2 years should be particularly important in determining technical reliability and evaluating the economic cost factors for full-scale equipment used in continuous operations.

Paper Fiber Recovery. The EPA-supported Black Clawson demonstration plant at Franklin, Ohio, has proven conclusively that a marketable fiber can be recovered from mixed waste using the wet processes (hydrapulping and liquid cyclone) adapted from the woodpulping industry.[9] The technology has high reliability; however, the fiber is of low quality compared to source-separated paper and marketability appears limited to use in relatively low-grade construction papers. Recently the technology has been directed more at producing a wet RDF fuel for boiler firing.

A dry process based on air classification and screening has also been applied to the recovery of paper for repulping. Although this technique has not been pursued very far in the U.S., three facilities have been operating in Italy recovering paper fiber from mixed waste using the Cecchini process.[10]

Ferrous Metals Recovery. Ferrous metal is the only material being universally included for recovery at mixed-waste processing facilities in use or in planning. Magnetic separation of ferrous metal has long been proven technically, and it is being practiced at transfer stations and landfill shredding sites as well as resource recovery plants. These are all instances where shredding or milling is performed prior to magnetic separation. During 1976 there were 30 to 35 such installations operating with a reported combined recovery of about 200,000 tons.[11]

In some facilities, the metal is run through secondary shredding, compaction, or other preparation to meet particular market requirements. The two principal markets currently are steelmaking and copper precipitation (primarily in the southwest). Detinning mills represent another important but relatively unexploited potential market, especially for the can fraction of the ferrous scrap. To date only a few detinning mills have utilized this post-consumer scrap.

Aluminum and Other Nonferrous Metals. Aluminum and other nonferrous metals are typically recovered from the inorganic or "heavy" fraction of the classified waste stream following shredding, organics separation and magnetic recovery of most of the ferrous metals. Recovery of aluminum and other nonferrous metal is closely related to glass recovery because when an operation is included to separate one of these materials from the inorganic stream, the remainder becomes more richly concentrated in the others.

Techniques exploiting differences in physical characteristics of the various inorganic materials have been widely adapted from the mineral processing and ore beneficiation fields. These have included grinding and screening, jigging, rising current, and heavy-media separation approaches. Many of these have proved highly useful in tests or pilot plants as preliminary processes for separating out the glass, sand, and lighter organics from the remaining metals. In addition, other approaches depending on differential electrostatic or electromagnetic properties have recently come under intensive investigation.

Electrostatic separation, involving the placement of static charges on materials, may be used to remove nonconductors, which hold the charge, from conductors (the metals), which do not. Similarly, it can be used to remove metallic contaminants from a glass-rich stream. This technique was tested in the EPA demonstration plant at Franklin and will be included in the commercial plant at Hempstead, New York.

Another process for extracting aluminum from a mixed inorganic fraction is the eddy current technology, often referred to as the "aluminum magnet," which depends on the electromagnetic properties of aluminum.[12] At least three private companies–Raytheon, Combustion Power Company, and Occidental Research–have developed prototype units of this type.

A Combustion Power Company unit, owned by

Alcoa, is now installed and undergoing tests at NCRR's Washington, D.C., testing facility. Alcoa and NCRR have recently added a double-stage "air knife" to this system, which is expected to increase aluminum purity by elimination of other metals and organic material carryover.[13] A commercial-size unit has been installed at Ames, and another is scheduled for the New Orleans plant in early 1977. Occidental's process will be tested in the EPA-supported pyrolysis demonstration plant in San Diego County, which is expected to begin operating in 1977. The Raytheon aluminum magnet is scheduled to be installed in the Monroe County, New York, facility, and the Bureau of Mines has added it to their flowsheet as a preconcentrator prior to electrostatic separation.

It thus appears that the eddy current process may be on the threshold of commercial application. However, a number of questions remain concerning product yields, purity, and market acceptance, and the process economics are therefore uncertain.

Glass Recovery. Glass-rich fractions may be extracted at various points in recovery plant systems–from trommel screens prior to primary shredding, from grinding and screening operations following air classification, or from media separation, jigging, or eddy-current processes. A crude recovered glass product may be marketable as a construction aggregate or fill material, or the product may be upgraded for the more stringent specifications of glass container or other market applications. Developmental work on such upgrading has focused mainly on two technologies, optical sorting and froth flotation.

Optical sorting of particles 1/4 to 3/4 inch in size to segregate clear from colored glass and to remove non-glass refractories has been demonstrated at the Franklin plant using equipment of the Sortex Company of North America. To date, however, the system has not eliminated ceramic and refractory contaminants to the degree necessary to meet the stringent specifications established by the glass industry (refractories cause imperfections in glass containers). In addition, yield has been somewhat lower than expected.

The economics of color sorting are questionable at this time, especially since the equipment is quite expensive. Nevertheless, color sorting may still prove viable for some locations since there appear to be more buyers in the glass industry for color-sorted than for mixed-color glass.

Froth flotation, the other basic method of glass recovery, is used as the final step after size and density separations to remove metals and organics and grinding to a very fine particle size. The process takes place in small tanks where, after addition of a chemical agent, the glass attaches to air bubbles flowing through the mixture and thus rises to the surface. Contaminants sink to the bottom.

Froth flotation has been tested by Occidental Research Company in a pilot plant and will be demonstrated in the EPA/Occidental demonstration plant in San Diego County, California. Recovery rates are estimated at above 90 percent of the process input feed and purity is 99+ percent. However, a significant quantity of the glass in the original waste may be lost at early stages of grinding, classifying, and screening. Also, although purity of the product is high, industry specifications are so stringent that it is uncertain whether they can consistently be met.

The U.S. Bureau of Mines has also experimented extensively with froth flotation and claims capability to meet container industry specifications for new containers. NCRR's testing and evaluation facility will conduct full-scale testing of froth flotation, and units have also been included in the final design of several commercial facilities, including those of Monroe County (New York) and New Orleans.

DEVELOPMENTS IN ENERGY RECOVERY

Energy can be recovered from municipal solid waste either directly by burning raw, as-received waste in a furnace with heat recovery facilities or by first upgrading the raw refuse by mechanical, thermal, or other processes to enhance its usefulness as a fuel. This section reports on current technical developments in energy recovery systems, including a comparative overview of energy recovery efficiencies.

System Summaries

For review purposes, energy recovery technologies can be grouped into five general categories (Table 20): (1) direct combustion; (2) mechanical processing; (3) pyrolysis; (4) bioconversion; and (5) the Brayton Cycle.

TABLE 20

A CLASSIFICATION OF ENERGY RECOVERY PROCESSES AND PRODUCTS

Processes	Principal fuel or converted energy products*
1. Direct combustion processes:	Steam; hot or chilled water
Refractory furnace	
Waterwall combustion boiler	
Small-scale package incinerator	
2. Mechanical separation of solid combustibles (RDF):	
Dry process (shredding and air classification)	"Fluff" RDF
	Dust RDF
	Densified RDF
Wet process (hydrapulping)	Wet RDF
3. Pyrolysis	Low Btu gas
	Medium Btu gas
	Liquid fuel
4. Bioconversion:	
Landfill	Methane
Anaerobic digestion	Methane
Acid hydrolysis	Methane, ethyl alcohol
Enzymatic hydrolysis	Methane, ethyl alcohol
5. Brayton cycle	Electricity/steam

*All fuels can, of course, be burned to produce steam. Steam in turn can be converted to electric energy or used directly for space heating, industrial processes, or other uses.

Direct Combustion Processes

Direct combustion of raw (or semiprocessed) municipal solid waste for energy recovery is by no means a new concept. There are presently over 250 facilities operating on this basis in Europe and Japan, and at least 12 facilities have this capability in the U.S. Earlier U.S. installations, dating from the early 1950's, were of the refractory-wall incinerator type, with waste-heat recovery boilers.^{7} This technology has since the late 1960's been superseded by the waterwall combustion technique based primarily on European design concepts and operating experience. More recently, small-scale package incinerators with heat recovery capabilities, originally designed for industrial and institutional applications, have begun to be adapted for municipal wastes.

Waterwall Combustion Furnaces. Waterwall units are widely employed in Europe and Japan, and there are now seven units completed in the U.S. Not all of them are marketing steam at present due to lack of customers, but at least four plants can be considered U.S. commercial prototype operations from the marketing as well as the technology standpoints. Somewhat surprisingly, there are currently no units of this type under construction in the U.S., although several are in the planning stages. The two newest units to come on line, at Nashville, Tennessee, and Saugus, Massachusetts, are worthy of further comment.

The Nashville Thermal Transfer Corporation facility (720 TPD) came on line in the summer of 1974 as an integral part of a district heating and air-conditioning system. The plant has now come to be recognized as a classic example of an unsuccessful attempt to build a low-cost system by "short-cutting" proven design criteria. The most notable development in 1975 was the major upgrading of the facility to correct design deficiencies. By the end of the year the facility was back in operation and producing steam to design standards. However, the original air pollution control systems did not meet emission standards and are being replaced.

The Saugus unit is a 1,200-TPD privately owned facility, completed in the fall of 1975 and financed by pollution control revenue bonds. It is the first U.S. plant to supply superheated steam to an industrial user on a commercial scale. The contracted tipping fee for communities delivering solid waste to the Saugus plant is about $14 per ton.

Small-Scale Package Incinerators. The small-scale package incinerator (under 50 TPD) with heat recovery module represents a new technology in its municipal applications and offers the prospect of energy conservation to relatively small communities. This concept has been employed by three communities–Blytheville and Siloam Springs, Arkansas, and Groveton, New Hampshire–to supply part of the steam requirements of local industry.

Mechanical Separation of Solid Fuels (RDF)

Mechanical separation processes under development and application in the U.S. include two broad types, loosely termed "dry" and "wet." Both have been actively supported by EPA demonstration funding.[9,14]

The "dry" process utilizes shredding (or milling) for size reduction of raw refuse, followed typically by some form of air classification to separate the particles into a light (primarily combustible organics) and a heavy (primarily noncombustible inorganics and hard-to-burn organic pieces) materials stream. The light fraction, without further processing, has generally come to be known as "RDF" (for refuse-derived fuel) or, more specifically, as "fluff RDF." This was essentially the fuel material produced by EPA's St. Louis demonstration project.[14] Processed further by physical or chemical means, it can become "densified RDF" (dRDF) or "dust RDF," according to current terminology.

Fluff RDF. EPA's demonstration unit to produce RDF at St. Louis proved the basic feasibility of the mechanical separation processes, transport and storage techniques, and the burning of fluff RDF in place of 5 to 27 percent of the pulverized coal in suspension-fired utility boilers without adverse short-term effects on boiler operations.

The production of fluff RDF is commercially available, although a great deal of work remains on the refinement of equipment components and the technical and economic optimization of the basic technology. The first commercial unit, the 400-TPD Ames, Iowa, facility, is only just beginning to accumulate operating experience. Three other larger units–in Baltimore County (550 TPD), Milwaukee (1,200 TPD), and Chicago (1,000 TPD)–are scheduled for completion in early 1977.

Densified RDF. The preparation of densified RDF is now being explored and evaluated.[15] Densified RDF is produced by pelletizing, briquetting, or extruding fluff RDF and is particularly adapted for stoker and spreader-stoker furnaces where fuels are burned on grates rather than in suspension. It has not been demonstrated commercially, and the costs, handling characteristics, and firing characteristics will be evaluated in ongoing projects.

Dust RDF. The basic feasibility of producing dust RDF (particles smaller than 0.15 millimeter) was demonstrated in a proprietary pilot-plant process in 1975 by Combustion Equipment Associates, Inc. After adding an embrittling chemical, coarsely shredded waste is pulverized to a dust-like consistency. A commercial-size plant is under construction at East Bridgewater, Massachusetts.

Dust RDF has a higher Btu content than fluff RDF (7,500 to 8,000 Btu/pound versus 5,000 Btu/pound); it also has greater density and homogeneity. In addition it may be capable of mixing and direct co-firing with conventional fuel oils. However, production costs are expected to exceed those for fluff RDF since more processing is required, and the dust-like composition may necessitate special handling to minimize the danger of an explosion. The benefit/cost comparisons between dust and fluff RDF are not yet known.

Wet RDF. The "wet" mechanical separation process utilizes hydrapulping technology adapted from the pulp and paper industry to reduce the raw waste to more uniform size and consistency, followed by a centrifugal, liquid cyclone process for separating the pulped mass into light and heavy fractions. The original solid waste application was at the EPA/Black-Clawson demonstration facility at Franklin, where the light fraction was further processed for fiber recovery and the nonfiber organic residual was burned in a fluid-bed combustion unit for disposal.[9] Future applications are planned primarily for energy recovery, with the fuel product now coming to be known as "wet RDF." Unlike other RDF, however, wet RDF is likely to be burned as the sole fuel for special on-site boilers rather than as a supplementary fuel in existing boilers.

Several test burns of the hydrapulped light fraction have been conducted in both suspension-fired and stoker-fired boilers. However, since the first full-size plants are only just nearing the construction stage (at Hempstead, New York, and Dade County, Florida) the system must be considered developmental from a boiler design and operations standpoint. These first boilers will be specially designed to burn the hydrapulped RDF to produce steam for electricity generation.

Pyrolysis

Pyrolysis is the physical and chemical decomposition of organic matter through the application of heat in an oxygen-deficient atmosphere. When municipal solid waste is thus processed, the organic fraction (primarily cellulose) is broken down, primarily into hydrogen, carbon monoxide, methane, and carbon dioxide. By controlling operating parameters such as temperature, pressure, residence time, and certain catalysts, it is possible to control the nature and composition of resulting products. Various pyrolysis process designs have been developed to derive gaseous and liquid fuels from municipal refuse.

Pyrolysis is largely in a developmental status, although two systems have been successfully operated at pilot stages.

Low Btu Gas. The first commercial-scale gas pyrolysis plant is the EPA-supported, Monsanto "Landgard" demonstration facility (1,000 TPD), which was constructed for the city of Baltimore and scheduled to begin operations in 1975.[16] The process yields a low-Btu gas (130 Btu/standard cubic foot), which is burned in an afterburner with a waste-heat boiler to generate steam for district heating and cooling in downtown Baltimore.

When completed in 1975, the plant exhibited significant design deficiencies attributable in large part to the scaling up from pilot plant to large commercial size. The principal problem stems from the fact that the reactor temperature is higher than expected and the residence time in the kiln is also longer than expected. This led to the formation of submicron particles (metallic salts) which were too small for collection by the scrubber, and emissions did not meet air pollution standards with the already installed pollution control equipment. Slagging and kiln refractory wear were also greater than anticipated. A 2-year modification program was begun in 1975 in which 96 system modifications were made. These modifications significantly improved plant operation but did not solve all of the problems. After unsuccessful attempts to complete 30 days of uninterrupted operation, Monsanto recommended that the plant be shut down, and their involvement in the project terminated in February 1977. The city is continuing to operate the plant and has completed a successful 30-day performance run at just over half of the plant's design capacity. The city plans to attempt two additional 30-day runs before making a final decision on spending several million dollars to make further plant modifications.

In the stage of early commercial operation is a process being marketed by the Andco Torrax Company. A 200-TPD plant began operation in mid-1976 in Luxembourg. Two other units of similar size are under construction in Europe. The Andco Torrax process is a high-temperature slagging pyrolyzer that produces low-Btu combustible gas. The technology was initially tested in an EPA-supported pilot plant.

Medium Btu Gas. Union Carbide's Purox System completed a series of pilot plant tests in 1975 at South Charleston, West Virginia. The process was tested using mixed municipal waste; it is now undergoing tests with sewage sludge co-disposal. Union Carbide now offers the system commercially. In addition to possible use as a fuel either on site or by a nearby customer, the Purox gas is believed to have potential as a feedstock to an on-site methanol or ammonia plant.

Liquid Fuel. A demonstration plant based on Occidental Petroleum Company's flash pyrolysis system has been constructed with EPA support in San Diego County, California.[17,18] The process produces an oil-like liquid with properties similar to No. 6 fuel oil. The plant is expected to begin operation in the summer of 1977.

Bioconversion

Bioconversion is the alteration of organic wastes through the action of a living organism, such as a fungus, yeast, or bacterium. Given time, nature can accomplish the biodegradation of wastes unassisted. Landfills, for example, anaerobically digest the cellulosic content of the fill to produce methane. The early results of work conducted in Palos Verdes, California, indicate that pipeline quality gas can indeed be processed from that collected from a landfill. Currently, EPA is evaluating the kinetics of gas recovery from a different kind of landfill located at Mountain View, California, and additional experimentation is being conducted under private sponsorship on at least four other sites.

Methane recovery from landfills is, in a sense, an afterthought to the disposal process. Bioconversion technologies developed specifically to maximize energy production include anaerobic digestion in reactors to produce methane, hydrolysis followed by anaerobic digestion to produce methane, and hydrolysis followed by fermentation to produce ethyl alcohol. In addition to the manufacture of methane and ethanol from cellulosic wastes, it is possible to produce glucose for chemical feedstocks, and protein for animal consumption.

EPA is currently conducting research on a 2-TPD anaerobic digestor, using municipal solid waste, at Franklin, Ohio. Results to date have indicated that mixing of the waste poses a significant problem that needs to be resolved before the process can be effective. Of greater interest is EPA-sponsored research involving acid hydrolysis of specially prepared municipal solid waste. While not in itself a biological conversion process, acid hydrolysis (like its biological cousin, enzymatic hydrolysis) is a precursor to various bioconversion options, such as production of glucose, methane, or ethyl alcohol. A recent technological breakthrough achieved has resulted in glucose conversions of up to 50 percent in 10 seconds. The competing enzymatic hydrolysis process has typically required hours to produce glucose conversions of only 30 percent. A 1-TPD acid hydrolysis pilot plant is now being developed by EPA to determine the kinetics of the process as conducted in a continuous reactor.

Brayton Cycle System

For several years EPA's Office of Research and Development has sponsored research on the Brayton Cycle. In this system high-pressure gases resulting from the combustion of solid waste with compressed air are directly used to drive a gas turbine. Combustion Power Company has carried out the work. Fluff RDF is combusted in a fluidized bed furnace and the cleaned gases are introduced into a gas turbine-generator to produce electricity.

Despite several years of effort, the system still has significant technical problems because the gases cannot be cleaned sufficiently to prevent unacceptable turbine damage. The latest work has been on a gas-cleaning process which would remove fine particles and other contaminants. However, a test unit failed structurally, and continuation of the effort to develop this system as a municipal solid waste processing option is in doubt.

The Energy Efficiency of Recovery Systems

The most common basis for expressing potential energy recovery from solid waste has been the gross energy content of raw waste (expressed in either Btu or equivalent barrels of oil). Although a useful first approximation, this has generally led to mistakenly high estimates of potential energy savings.[19] The reason for this is that the gross or latent energy content can never be entirely captured as useful energy. First, if a mechanical separation process is employed, some portion of the energy will be physically lost as part of the "heavies" reject stream. In addition, if the process involves conversion of material from one form to another via thermal or chemical processes, there will be substantial losses (mainly in the form of waste heat) due to conversion inefficiencies. Net energy contained in the recovered fuel output stream can therefore be substantially less (by 50 percent or more) than the gross energy content of the total waste input stream.

It must also be recognized that any material handling and processing operation must itself require fuel and electricity. These energy input requirements must be included in calculations of a plant's overall energy balance.

EPA's preliminary calculations of the net energy efficiencies for a number of recovery processes are presented in Table 21.[20] The calculations are based to the extent possible on actual measured energy balances for existing operating or pilot facilities, but in many instances they necessarily reflect preliminary engineering estimates. The column showing net energy available as steam has been calculated to provide additional important comparisons among the different fuels (since the conversion efficiencies of the different fuels to steam differ markedly), and to allow valid comparison between direct conversion to steam (waterwall furnace) versus intermediate fuel production. Others have published similar estimates of energy efficiencies of recovery techniques.[21]

TABLE 21

COMPARISON OF ENERGY RECOVERY EFFICIENCIES FOR SELECTED SOLID WASTE ENERGY RECOVERY PROCESSES*

(Percent of higher heat value contained in input solid waste)

Process	Net energy in fuel produced†	Net energy available as steam‡
Fluff RDF	74	58
Dust RDF	80	63
Wet RDF	76	48
Waterwall combustion furnace	–	59
Purox gasifier	64	58
Monsanto gasifier	78	42
Torrax gasifier	65	37
Occidental Petroleum Co. pyrolysis	26	23
Biological gasification §		
With use of residue	29	24
Without use of residue	16	14

*EPA data from reference 20. All calculations based on solid waste input at 5,000 Btu per pound (higher heating value) with some inorganic materials removed.

†This is the higher heating value of the fuel product less the heat value of the energy used to operate the system (in the case of electric power consumption it was assumed that the electricity was produced on site using the system's fuel product), expressed as a percent of the heat value of the input solid waste.

‡In order to compare all the processes on an equal basis, the net energy available as steam was calculated using the boiler efficiency for each fuel product.

§ Includes energy recovered from sewage sludge.

In general, the less processing the waste undergoes, the greater the net energy recovered for useful application as a fuel and the less process energy required. Thus, pyrolysis, which creates a more refined intermediate fuel product, is less energy efficient than RDF, which makes no chemical change in the waste material. However, the gas, liquid, or steam product would be expected to sell for a higher price and may therefore be economically justified.

Even though based on incomplete data, the net energy calculations presented constitute an important technical advance in our understanding of alternative energy recovery processes.

DEVELOPMENTS IN PROCUREMENT AND FINANCING

Communities that have actively engaged in implementing large-scale resource recovery systems have found that they must deal with more than just technological choices. They must also make decisions regarding managing/operating, procuring, and financing of recovery facilities, as well as the marketing of recovered products.

Methods that communities have followed in financing and constructing large-scale resource recovery systems are summarized in Table 22. The table lists the procurement methods, financing options, management systems, and principal product markets, as of July 1976, for all U.S. facilities in excess of 300 tons per day capacity either built or contracted for since 1967. It does not include installations that only shred and magnetically scalp ferrous metal from the solid waste.

The data show that no single pattern or model has been established in financing, procuring, or managing recovery systems. Options have varied to meet the specific objectives and constraints of a given locality. Almost all facilities have been financed by tax-exempt, long-term debt obligations, however. In addition, all except one of the projects is dependent on energy revenue, and most recent projects sell to the electric utility industry. Seven new recovery facilities–located in Bridgeport, Milwaukee, Hempstead, Saugus, Chicago, St. Louis, and North Little Rock–were financed during the past year.

TABLE 22

FINANCING AND PROCUREMENT APPROACHES FOR LARGE-SCALE RESOURCE RECOVERY PLANTS CONTRACTED FOR SINCE 1967*

Location	Financing method	Procurement method	Project management	Type	Capacity (tons/day)	Market
Systems in operation:						
Ames, Iowa	City GO bonds	A&E	City	RDF	400	City-owned utility
Harrisburg, Pa.	Revenue bonds	A&E (partial turn-key)	City	WWC	720	Steam heating loop
Nashville, Tenn.	Revenue bonds	A&E	Nonprofit corporation	WWC	720	Steam heating and cooling loop
Norfolk, Va.	U.S. Navy appropriation	A&E	U.S. Navy	WWC	360	Steam, Navy base
Saugus, Mass.	Pollution control revenue bonds	Full-service (Industry initiative)	Private corp.	WWC	1,200	Steam, industrial plant
Systems under contract:						
Baltimore, Md.	Federal grant, State loan, city funds	Turn-key	City	Pyrolysis	1,000	Steam heating loop
Baltimore County, Md.	State reimbursable county GO bonds	A&E	Private corp.	RDF	550	Cement plant
Bridgeport, Conn.	State revenue bonds (moral obligation)	Full-service	Private	RDF	1,800	Materials industries, utility
Chicago, Ill.	City GO bonds	A&E	City	RDF	1,000	Utility
Dade County, Fla.	State GO bonds	Full-service	Private corp.	WRDF/WWC	3,000	Utility, materials industries
Hempstead, N. Y.	Pollution control revenue bonds	Full-service	Private corp.	RDF, WWC	2,000	Utility, materials industries
Milwaukee, Wis.	Private	Full-service	Private corp.	RDF	1,000	Utility, materials industries
Monroe County, N. Y.	State grant, public improvement bonds	A&E (partial turn-key)	Private corp.	RDF	2,000	Utility
New Orleans, La.	Private	Full-service	Private	RDF	650	Materials industries
St. Louis, Mo.	Pollution control revenue bonds	Full-service	Private	RDF	6,000	Utility

*Resource Recovery Division, Office of Solid Waste, EPA.

Abbreviations and definitions: RDF = refuse-derived fuel system; WWC = waterwall combustion; WRDF = wet-pulped refuse-derived fuel; GO = general obligation; A&E = architect and engineers perform feasibility study, design facility, supervise equipment bidding; turn-key = contractor designs, constructs, and guarantees performance of facility to meet acceptance tests; full-service = contractor designs, builds, and operates facility.

An important institutional development with respect to financing occurred when the U.S. Internal Revenue Service ruled favorably on the use of pollution control revenue bonds (PCRB's) in financing recovery projects. PCRB's are tax-exempt bonds issued through a public entity on behalf of a private enterprise. The municipality acts only as a vehicle through which the corporation may obtain low-cost financing. On June 20, 1975, the IRS published in the *Federal Register* "temporary" regulations delineating use of PCRB's for financing solid waste facilities. Since then, IRS has ruled favorably on the Saugus, Hempstead, New Orleans, and St. Louis (Union Electric Co.) applications.

The IRS rules address both materials and energy recovery. Basically, they allow tax-exempt status for all types of materials recovery plant and equipment to separate materials from the mixed waste stream, plus all equipment at the recovery plant necessary to beneficiate the recovered products to make them more commercially acceptable or to increase their market value. The rules specifically exclude beneficiation facilities and equipment for further processing at the commercial user's plant.

With respect to energy recovery, the rules allow tax-exempt status for all assets to convert the waste into usable energy, including extra equipment that may be necessary to upgrade the product to meet the specifications of its particular market. The rules exclude equipment for transporting the product after processing "into the form in which it is sold" (e.g., via steam pipes or trucks). The rules also exclude electricity generating equipment from tax-exempt financing, "since the equipment transforms the commercially salable steam into another form of energy."

Resource recovery facilities can be financed through taxable (corporate) or tax-exempt (general obligation, State or municipal revenue, or pollution control revenue) bonds. In most circumstances, it should be assumed that tax-exempt bonds will be the primary method for financing recovery projects, because taxable, corporate bonds will usually be a more expensive form of financing. The one exception to this statement thus far has occurred in Milwaukee, where Americology (a subsidiary of the American Can Company) did finance a project with taxable debt. Americology has since stated, however, that it would not finance future projects in a similar fashion, and was only willing to use taxable debt to insure that the Milwaukee plant, their first and showcase project, would be built in a timely fashion.

STATE ACTIVITIES AND ASSISTANCE

In numerous instances State governments have taken a direct and active role in the implementation of resource recovery (Table 23).

For example, some States have supported resource recovery planning efforts at the local level by issuing planning grants or providing State agency expertise to municipalities or regions to conduct feasibility studies. Many States have also engaged in direct statewide planning to determine needs and marketing potentials, alternative regional plant sites, and overall recovery strategies.

In other instances, certain States have taken steps to regulate recovery activities. This regulation can range from control over the supply and disposal of solid waste to authority to own and operate resource recovery facilities. At the present time, according to EPA's nationwide survey, 21 States are involved directly in resource recovery planning or regulation.

Many States also assist in financing the construction of resource recovery facilities through the establishment of either State grant or loan programs. Such action can ease the financing burden of the cities and stimulate implementation by either subsidizing part of the capital costs outright or by making available low-interest loans to the communities, thereby reducing interest expenses. EPA's nationwide survey presently lists 11 States with the authority to underwrite loans or make grants for facilities construction. The number was increased during the past year by the addition of California, which authorized $200 million in tax-exempt bonds for construction of recovery facilities. Although provided with the authority, however, not all of these States have appropriated or approved funding for projects.

In another related effort, North Carolina has enacted legislation authorizing favorable tax treatment for certified resource recovery facilities. Such a certification exempts a facility from county real estate taxes and permits a 60-month writeoff for State tax purposes.

TABLE 23

SUMMARY OF STATE ACTIVITY IN RESOURCE RECOVERY, 1976*

States involved in planning or regulation (21)	Grant or loan authority (11)	Operating authority (6)
California	$200 million, loans	
Connecticut	$250 million, loans	x
Florida	$200 million†	x
Hawaii		
Illinois	$6 million, grants	
Maryland	$15 million‡	x
Massachusetts	$10 million§	x
Michigan		
Minnesota	$3.5 million, grants	
Montana		
New York	$175 million, loans	
North Carolina		
Ohio		
Oregon	$2.5 million, grants	
Pennsylvania		
Rhode Island		x
South Dakota		
Tennessee	$49.3 million, loans; $2.4 million, grants	
Vermont		
Washington	$30 million, grants & loans	
Wisconsin		x

*Resource Recovery Division, Office of Solid Waste, EPA.

†This is total available for air, water, and solid waste programs.

‡Total available for resource recovery and other solid waste management.

§Bonding authority for land acquisition.

Finally, six States—Connecticut, Florida, Maryland, Massachusetts, Rhode Island, and Wisconsin—have enacted legislation providing for special State authority (or for the formation of nonprofit public corporations with State backing and authority) to engage directly in facilities design and construction or procurement contracts and, in some instances, authority to operate facilities.

The *Third Report to Congress* contained descriptions of activities for most of the States listed in Table 23. For more recent descriptions, the reader is referred to EPA's revised *Nationwide Survey.*[6] In addition, a 1976 publication of the National League of Cities/United States Conference of Mayors provides a comprehensive current review of State programs.[22]

FEDERAL ASSISTANCE PROGRAMS

Many communities do not have sufficient experience to implement a successful resource recovery project, which is a business endeavor quite different from traditional solid waste management activities. Communities need information to address in a timely and effective manner such issues as project management, public education, evaluation of different technologies, marketing of products, project financing, management of risks, and drafting of appropriate procurement documents and contracts.

To address these needs, EPA has established a Resource Recovery Technical Assistance Program. Its objectives are to transfer experience that has been gained among local governments as well as information and results from EPA's own research, development, technology demonstration, and analysis efforts. The program has two main elements: information and consultation. These are supplemented by a limited financial assistance program of project implementation grants.

Through contract and in-house efforts, information has been developed and made available on a wide array of topics relating to resource recovery. The major recent output of this effort is the eight-part series: *Resource Recovery Plant Implementation: Guides for Municipal Officials*, which constitutes a comprehensive guide to planning and procuring a system; the topics include: Planning and Overview, Financing, Risks and Contracts, Accounting, Procurement, Technologies, Markets, and Further Assistance (a list of information sources).[20, 23-29]

EPA also provides in-depth consultation to a limited number of communities who are familiar with resource recovery, demonstrate political commitment to implementation, and are willing to work closely with a technical assistance team. Assistance is oriented towards helping State and local governments decide what tasks should be performed. Performance of these tasks is generally left to the State or local government and its consultants.

A local government must complete two phases of activities to determine if resource recovery is feasible and should be implemented in its area. The Technical Assistance Program can provide aid in both these phases. In the study and planning phase, technologies, costs, markets, management structures, financing arrangements, and procurement options are identified and analyzed. Information and assistance in this area has been given to many State and local government agencies.

The second phase involves selection and procurement activities leading directly to the acquisition and construction of a facility or other project. Activities in this phase include writing and reviewing a request for proposals (RFP), developing evaluation criteria, reviewing responses to the RFP, critiquing design, analyzing risks, developing a negotiating strategy, and negotiating of contracts for construction, operation, or the sale of products. Assistance in these areas requires close work with a city over an extended period of time. In recent months, such assistance has been given to the following localities:

Dade County, Florida	Assisted in evaluation of proposals.
Detroit, Michigan	Assisted city in writing request for proposals (RFP), in deciding on major system parameters, and in evaluating proposals to build and operate a facility.
Lane County, Oregon	Advised city on preparation of RFP and recommended presolicitation meeting with potential bidders.
Lexington, Kentucky	Advised city on risk management and system selection; provided design review.
Memphis, Tennessee	Presented evaluation of proposals to city council and proposed decision-making procedures.
Montgomery County, Ohio	Advised city on procurement strategy.
Washington, D.C.	Evaluated merits of system under consideration by city council.

The Bureau of Mines of the Department of the Interior also provides technical assistance to communities committed to resource recovery, particularly those planning to adopt Bureau of Mines technology in whole or in part. Frequently this includes comprehensive tests on the communities' refuse in the Bureau's Resource Recovery Pilot Plants. Some communities that have recently been provided assistance on raw refuse processing include: St. Petersburg and Tampa, Florida, Tulsa, Oklahoma, Rochester, New York, the counties of Baltimore, Montgomery, and Howard in Maryland, and Mifflin County, Pennsylvania. In addition the Bureau supplied engineers to serve on design review committees for the projects at Monroe County, New York, and Montgomery County, Maryland.

Besides working directly with State and local governments, EPA works closely with many public interest, advocacy, and industry groups to further understanding of resource recovery. The agency has participated in conferences sponsored by the National League of Cities/U.S. Conference of Mayors, National Association of Counties, National Solid Waste Management Association, the American Public Works Association and the League of Women Voters. EPA has provided grants to many of these organizations and others for the education of their constituencies regarding the issues in resource recovery and solid waste management in general.

EPA Implementation Grants

EPA has observed that many local governments are unable or reluctant to budget funds to hire professional consultants to supplement their own resources for planning resource recovery projects. To stimulate the implementation of systems and to demonstrate proper planning practices, EPA recently instituted a program of implementation grants to State, regional, and local governmental (or quasi-governmental) agencies.

EPA received funds for and announced the availability of these grants in March and October 1975. Table 24 indicates the response to each announcement and the awards that were made. The amount of funds available was small relative to the number of applicants and amounts requested, and many qualified applicants had to be denied.

To be eligible, applicants were required to submit a detailed work plan that described tasks leading directly to implementation of a system (signing of contracts for construction, sale of products, and supply of waste). Applicants were required to demonstrate their commitment to follow through by providing cash or in-kind services to pay for at least 25 percent of the pre-design and pre-construction project costs. In the first round, only energy recovery projects were eligible. In the second round, proposals were also invited for materials recovery, source separation, and waste reduction projects.

TABLE 24
RESOURCE RECOVERY IMPLEMENTATION GRANT PROGRAM SCHEDULE AND AWARD DECISIONS

	First round	Second round
Program announced	March 1975	October 1975
Applications received:		
Date	April 1975	December 1975
Number	102	99
Amount requested	$7.2 million	$4.5 million
Grants awarded:		
Date	June 1975	June 1976
Number	8	9
Amount	$440,000	$350,000
Grantees selected:		
	Denver Regional Council of Governments, Colo.	Charlottesville, Va.
	Lane County, Oreg.	Detroit, Mich.
	Lexington-Fayette Urban County Government, Ky.	Duluth, Minn.*
	Middlesex County, N. J.†	Nez Perce County, Idaho*
	Montgomery County, Ohio	San Luis Obispo County, Calif.*
	New York, N. Y.	Springfield, Ill.
	Rhode Island Solid Waste Management Corporation†	Stanislaus County, Calif.*
	Richmond, Va.	State of Maryland
		Commonwealth of Massachusetts

*Represent implementation grants for source separation resource recovery projects.

†In June 1976, Middlesex County and the Rhode Island Solid Waste Management Corporation grants were supplemented with $100,000 and $50,000, respectively, under the areawide planning authority (Section 208) of the Federal Water Pollution Control Act (P.L. 92-500). The scope of work for the two grants was expanded correspondingly.

REFERENCES

1. Levy, S. J. Markets and technology for recovering energy from solid waste. Environmental Protection Publication SW-130. Washington, U.S. Environmental Protection Agency, 1974. 31 p.

2. Levy, S. J. Materials recovery from post-consumer solid waste. Presented at 3d U.S.-Japan Conference on Solid Waste Management, Tokyo, May 12-14, 1976. Washington, U.S. Environmental Protection Agency. 33 p.

3. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.

4. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and waste reduction; third report to Congress. Environmental Protection Publication SW-161. Washington, U.S. Government Printing Office, 1975. 96 p.

5. Hopper, R. E. A nationwide survey of resource recovery activities. Environmental Protection Publication SW-142. [Washington], U.S. Environmental Protection Agency, Jan. 1975. 74 p.

6. McEwen, L. A nationwide survey of waste reduction and resource recovery activities. Environmental Protection Publication SW-142.1. Washington, U.S. Environmental Protection Agency, 1977.

7. Alvarez, R. J. Status paper on conversion of solid waste to energy on the North American continent. *In* Conference papers; CRE, Conversion of Refuse to Energy; 1st International Conference and Technical Exhibition, Montreux, Switzerland, Nov. 3-5, 1975. p. 130-135.

8. Specifications for recovered materials. pt. I. *NCRR Bulletin*, 5(4):86-96, Fall 1975; pt. II. A prerequisite to marketing. 6(1):13-22, Winter 1976.

9. Arella, D. G. Recovering resources from solid waste using wet-processing; EPA's Franklin, Ohio, demonstration project. Environmental Protection Publication SW-47d. Washington, U.S. Government Printing Office, 1974. 26 p.

10. Resource recovery; experience and systems description. Bethpage, N. Y., Grumman Ecosystems Corporation, Jan. 1975. 27 p.

11. Resource Technology Corporation. Solid waste processing facilities. Technical Report 103701, Rev. B. Washington, American Iron and Steel Institute, Feb. 1976. 358 p. Also Resource Technology Corporation unpublished data.

12. Morey, R., and S. Rudy. Aluminum recovery from municipal trash by linear induction motors. Presented at 78th National Meeting, American Institute of Chemical Engineers, Salt Lake City, Utah, Aug. 18-21, 1974. 17 p.

13. The aluminum magnet: closing the loop: aluminum production, use, recovery, reuse. Pittsburgh, Aluminum Company of America, 1976. 8 p.

14. Lowe, R. A. Energy recovery from waste; solid waste as supplementary fuel in power plant boilers. Environmental Protection Publication SW-36d.ii. Washington, U.S. Government Printing Office, 1973. 24 p.

15. National Center for Resource Recovery. Preparation, use and cost of d-RDF as a supplementary fuel in stoker fired boilers. U.S. Environmental Protection Agency, Office of Research and Development Grant No. R804150.

16. Sussman, D. B. Baltimore demonstrates gas pyrolysis; resource recovery from solid waste. Environmental Protection Publication SW-75d.i. Washington, U.S. Government Printing Office, 1975. 24 p.

17. Levy, S. J. San Diego County demonstrates pyrolysis of solid waste to recover liquid fuel, metals, and glass. Environmental Protection Publication SW-80d.2. Washington, U.S. Government Printing Office, 1975. 27 p.

18. Preston, G. T. Resource recovery and flash pyrolysis. *Waste Age*, 7(5):83-86, 89-90, 92, 94, 96, 98, May 1976.

19. Lowe, R. A., M. Loube, and F. A. Smith. Energy conservation through improved solid waste management. Environmental Protection Publication SW-125. Cincinnati, U.S. Environmental Protection Agency, 1974. 39 p., app.

20. Levy, S. J., and H. G. Rigo. Resource recovery plant implementation: guides for municipal officials—technologies. Environmental Protection Publication SW-157.2. [Washington], U.S. Environmental Protection Agency, 1976. 81 p.

21. Bailie, R. C., and D. M. Doner. Energy accounting procedure for evaluation of efficiency of resource recovery systems. *Resource Recovery and Conservation*, 1(2): 177-187, 1975.

22. Heidenreich, P., and R. A. Lowe. Resource recovery planning . . . an overview of the implementation process. Washington, National League of Cities, United States Conference of Mayors, [1976]. 21 p.

23. Shilepsky, A., and R. A. Lowe. Resource recovery plant implementation: guides for municipal officials—planning and overview. Environmental Protection Publication SW-157.1. [Washington], U.S. Environmental Protection Agency, 1976. 34 p.

24. Garbe, Y. M., and S. J. Levy. Resource recovery plant implementation: guides for municipal officials—markets. Environmental Protection Publication SW-157.3 [Washington], U.S. Environmental Protection Agency, 1976. 47 p.

25. Randol, R. E. Resource recovery plant implementation: guides for municipal officials—financing. Environmental Protection Publication SW-157.4. [Washington], U.S. Environmental Protection Agency, [1975]. 20 p.

26. Mitre Corporation. Resource recovery plant implementation: guides for municipal officials—procurement. Environmental Protection Publication SW-157.5. [Washington], U.S. Environmental Protection Agency, [1976]. 66 p.

27. Sussman, D. B. Resource recovery plant implementation: guides for municipal officials—accounting format. Environmental Protection Publication SW-157.6. [Washington], U.S. Environmental Protection Agency, [1976]. 17 p.

28. Randol, R. E. Resource recovery plant implementation: guides for municipal officials—risks and contracts. Environmental Protection Publication SW-157.7. [Washington], U.S. Environmental Protection Agency, 1976. 52 p.

29. Hawkins, D. Resource recovery plant implementation: guides for municipal officials—further assistance. Environmental Protection Publication SW-157.8. [Washington], U.S. Environmental Protection Agency, [1975], 29 p.

Chapter 6

ENVIRONMENTAL AND ECONOMIC IMPACTS OF NATIONAL BEVERAGE CONTAINER DEPOSIT LEGISLATION

INTRODUCTION

In recent years there have been numerous proposals at the Federal, State, and local levels to require mandatory deposits on all beer and soft-drink containers. The purpose of such deposits is to provide a direct financial incentive to consumers to return empty beverage containers to points of purchase (or other redemption points) for reuse or recycling, thus diverting them from municipal solid waste collection, disposal, and littering. Reuse and recycling of containers also result in savings of energy and materials.

Four States–Oregon, Vermont, Michigan, and Maine–now have such laws in effect. The U.S. Senate in the 1976 session voted against a proposal that would have instituted mandatory deposits nationwide. Many of those voting against this proposal indicated that they felt that they did not have sufficient information to make an informed judgment.

At the request of Congress, EPA has carried out an analysis of the environmental and economic impacts of such a law. This chapter presents EPA's findings in the areas of:

Litter reduction
Energy savings
Material savings
Solid waste reduction
Employment effects
Industrial investment requirements
Consumer beverage price changes

The results presented are based upon a number of analyses, studies, and investigations conducted by EPA staff, consultants, and contractors, as noted in the references at the end of the chapter. The Federal Energy Administration and the Department of Commerce have also carried out analyses of many of these issues,[1,2] and comparisons with their results are provided where feasible.

CONTAINER MARKET SHARE SCENARIO AND OTHER ASSUMPTIONS

The economic and environmental impacts of container deposit legislation depend upon the change in the market shares of different container types and the time period over which this change takes place. The general consensus is that deposit legislation would result in an increased use of refillable glass bottles at the expense of nonrefillable bottles and metal cans. However, the precise extent and rapidity of the shift are subject to debate.

Many previous analyses of deposit legislation have assumed an extreme and sudden market response involving complete elimination of both nonrefillable bottles and metal cans in a very short period of time following enactment.[2,3] This does not appear to be a feasible or likely market response for several reasons.

Deposit legislation under consideration does not ban or prohibit the use of metal cans or nonrefillable bottles but merely requires a refundable deposit on whatever container is used. With deposit legislation, a nonrefillable bottle and a refillable bottle may be identical in the eyes of the consumer. If so, container choice would be made on the basis of price alone (rather than on the basis of price *and* convenience in a situation where nonrefillable bottles do not carry deposits). Since beverages in refillable bottles are typically much less costly than beverages in nonrefillable bottles, the former would be purchased whenever they represent perfect substitutes for the latter. However, in certain container sizes (especially quart and larger sizes) beverages in refillable containers are not always available. Also, some consumers might prefer nonrefillable bottles because of their lighter weight (this may be particularly important for the larger sizes). Furthermore, certain beverage producers could choose to stay with nonrefillable bottles for product distinction, and imported beer may continue to be sold in such bottles. Therefore, while it is reasonable to expect a significant decline in nonrefillable bottle usage under a national deposit system, it is not obvious that such containers would be eliminated altogether.

Usage of metal cans may be less deeply affected. The metal can is the highest priced beverage container in use today, and some consumers are paying a premium for beverages in cans even as compared to nonrefillable bottles. For these consumers, metal cans apparently provide certain benefits beyond the convenience of not having to return the container, perhaps ease of storage, lighter weight, or shatter resistance. Such perceived advantages, together with greater value of metals over glass as material for recycling, could cause the metal can to fare much better than the nonrefillable bottle under a universal deposit system. This is suggested by the recent successes of the aluminum industry's can recycling efforts, where substantial fractions are returned for a small refund (three-quarters of a cent per can).

While it is difficult to estimate the extent of market shifts, it is perhaps even more difficult to estimate the *rate* at which such shifts would take place. The availability of both containers and on-line filling equipment capacities would affect this rate, as would a host of other industry adjustment factors. In the present analysis, it has been assumed that a uniform national deposit law was enacted at the end of 1975 and that the container mix transition occurs over the 5-year period from 1975 to 1980.

Based on considerations such as the above, together with results of the Oregon and Vermont experience, the following shift in market shares was assumed for the EPA impact analysis:

- Growth in the refillable bottle share of the combined beer and soft-drink market to 80 percent from 25 percent in 1975.
- Decline in the use of one-way glass bottles and elimination of such containers by the end of the transition period, contrasted with a 27-percent market share in 1975.
- Decline of metal cans to 20 percent of the market (shared equally by aluminum and steel cans) from 47 percent in 1975.

Other assumptions are:

- Beverage consumption does not change as a result of legislation. (This is consistent with findings by the Research Triangle Institute on the price effects and price elasticities of demand for beer and soft drinks.[1,3])
- 90 percent of refillable bottles are returned and refilled. (This is equivalent to a "trippage" rate of 10, which is considered realistic, both in light of present national experience and the Oregon-Vermont deposit experience.)
- 90 percent of the aluminum and steel cans are returned, and 90 percent of those returned are recycled. (The same return rate as for glass seems the most reasonable assumption. The recycling rate assumption is arbitrary.)
- The container weight and size mix does not change during the transition period. (A simplifying assumption.)
- The plastic bottle does not enter the market during the transition period. (A simplifying assumption.)

In the analysis this deposit scenario is compared to a baseline container mix for 1980 projected in the absence of deposit legislation (Table 25). The latter data are based on an EPA contract study of technical and economic trends in the beverage, container, and metals industries.[4]

While the assumptions concerning market shares, transition period, and return and recycling rates are to some extent arbitrary, they do not constitute an unreasonable working model for estimating the impacts of such legislation. If anything, the assumed change in container mix perhaps represents a more extreme market shift over this period than would actually be realized. If this is true, then the analysis will tend to overestimate changes in employment and capital costs, and, to some extent, environmental and conservation benefits as well. However, the environmental, energy, and resource conservation benefits are more sensitive to the return, reuse, and recycling rates achieved than to the changes in container mix as such.

TABLE 25

DISTRIBUTION OF THE BEVERAGE CONTAINER MARKET AMONG CONTAINER TYPES, FOR BEER AND SOFT DRINKS COMBINED*
(Percent of packaged volume)

	Refillable glass bottles	One-way glass bottles	Steel cans	Aluminum cans
1975 baseline	26	27	31	16
1980 baseline	21	28	30	21
1980 deposit legislation	80	0	10	10

*EPA analysis of data from: Nuss, G. R., et al. [Midwest Research Institute]. *Base Line Forecasts of Resource Recovery, 1972 to 1990: Final Report.* Environmental Protection Publication SW-107c. U.S. Environmental Protection Agency, 1975. [386 p.] (Distributed by National Technical Information Service, Springfield, Va., as PB-245 924.)

RESULTS

Litter Reduction

The analysis of the impact of national container deposit legislation on roadside litter is based upon the results of similar legislation in Oregon and Vermont. A study sponsored by the Oregon State Legislature estimated that beverage container litter declined by 66 percent in the year following enactment of the legislation.[5] A study by the Oregon Environmental Council found that beverage container litter was reduced by 72 percent during the first year and by 83 percent during the second year following the passage of the legislation.[6] Both of these studies utilized data collected through controlled litter surveys conducted by the Oregon State Highway Division. A Vermont Highway Department litter survey found a 67 percent reduction in beverage container litter in the year following passage of legislation in that State.[7] All of these results have been reviewed and analyzed and are believed to correctly represent the impact of these laws on beverage container litter.

Amounts of beer and soft drink containers that would be littered on highways with and without container deposit legislation were estimated and projected using litter rates from these and other surveys. The results indicate that approximately 4.1 billion containers were littered in 1975; the projected figure for 1980 is 5.3 billion (Table 26). If a nationwide deposit system were in effect, it is estimated that beverage container litter would be reduced to 1.6 billion containers in 1980. This figure is 60 percent below the 1975 level and 70 percent below that projected for 1980 in the absence of deposit legislation.

Litter surveys have shown that beer and soft-drink containers comprise between 20 to 30 percent of roadside litter by item count and 40 to 60 percent on a volume basis. In Oregon, total roadside litter was reported to be reduced by 11 to 26 percent on an item count basis and 35 percent on a volume basis the first year after the bill went into effect.[5,6] During the second year, a reduction in total roadside litter of 39 percent by item count and 47 percent by volume was reported.[6] National beverage container deposit legislation is thus expected to result in significant reductions in roadside litter.

Energy Savings

Energy requirements for various container systems were analyzed. The analysis included the energy required for each manufacturing and transportation step in the life cycle of the container, beginning with the extraction of raw materials from the earth and continuing through materials processing, product fabrication, use, and final disposal (or reuse and recycling). The analysis employed 1973 energy consumption factors.

The EPA analysis indicates there are considerable energy savings when beverage containers are reused or recycled. For example, a glass bottle reused 10 times consumes less than one-third of the energy of single-use containers used to deliver the equivalent quantity of beverage.[8] Recycling of aluminum and all-steel cans saves 78 and 39 percent, respectively, of the energy required to manufacture cans from virgin raw materials.[8]

TABLE 26

AMOUNTS OF LITTER OF BEER AND SOFT DRINK CONTAINERS*

Year	Billions of containers
1975 baseline	4.1
1980 baseline	5.3
1980 deposit legislation	1.6

*EPA analyses based on data from: Finkner, A. L. *National Study of the Composition of Roadside Litter*. Report from the Highway Research Board to Keep America Beautiful. Research Triangle Park, N.C., Research Triangle Institute, Sept. 12, 1969. 137 p. (Unpublished report.); and Waggoner, D. *Oregon's Bottle Bill Two Years Later*. Portland, Ore., Columbia Group Press, May 1974. 37 p., app.

In the absence of container legislation, energy consumption for the beverage container industry is projected to be 585 trillion Btu in 1980. Container legislation would reduce this by 245 trillion Btu that year and in fact would reduce energy consumption below the 1975 baseline levels (Table 27).

An energy saving of 245 trillion Btu per year is equivalent to a saving of 125,000 barrels of oil per day. While this would be less than 1 percent of total national energy consumption in 1980, it is comparable in magnitude to other important energy conservation measures. For example, it is equivalent to one-half of the energy saving from nationwide adherence to the 55-mile-per-hour vehicle speed limit.

TABLE 27

ANNUAL ENERGY CONSUMPTION BY BEVERAGE CONTAINER SYSTEMS*

Year	Trillion Btu
1975 baseline	465
1980 baseline	585
1980 deposit legislation	340

*EPA analyses of data from: Hunt, R.G., et al. *Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives; Final Report.* v. 1-2. Environmental Protection Publication SW-91c. Washington, U.S. Government Printing Office, 1974. 178 p.

The Federal Energy Administration recently completed an energy savings analysis similar to the one previously conducted by EPA.[1] However, the FEA study accounted for technology changes that may reduce energy consumption in the beverage industry in future years. This study also made different assumptions concerning container market shares and return and recycling rates. The FEA study estimates annual energy savings ranging from 145 to 170 trillion Btu in 1982 depending upon the assumptions made. While these savings are lower than those previously predicted by EPA, they still represent substantial levels of energy conservation for this industry (reductions in energy consumption of 38 to 44 percent).

Solid Waste Reduction and Material Savings

Savings in virgin raw materials and reduction in solid waste result from the reuse and recycling of containers. Estimates of virgin raw material usage for both the baseline case (in the absence of container deposit legislation) and the container deposit scenario indicate that deposits would result in a savings of 530,000 tons of aluminum, 1.5 million tons of steel, and 5.2 million tons of glass per year by 1980 (Table 28). Furthermore, under a deposit law, 1980 material consumption would drop below even 1975 baseline conditions.

TABLE 28

VIRGIN RAW MATERIAL CONSUMPTION FOR PRODUCTION OF BEVERAGE CONTAINERS*

(Millions of tons per year)

Year	Aluminum	Steel	Glass
1975 baseline	.475	1.49	6.79
1980 baseline	.643	1.74	8.24
1980 deposit legislation	.112	.29	3.00

*EPA analyses of data from: Hunt, et al., *Resource and Environmental Profile Analysis*, 1974.

Deposit legislation is projected to reduce the beverage container component of solid waste by 70 percent, or 7.2 million tons, in 1980 (Table 29). This represents approximately a 5-percent reduction in total residential and commercial solid waste generated in that year (or 8.5 percent of the manufactured goods, excluding food and yard trimmings, in the waste stream).

TABLE 29

BEVERAGE CONTAINERS IN MUNICIPAL SOLID WASTE*

Year	Million tons
1975 baseline	8.8
1980 baseline	10.6
1980 deposit legislation	3.4

*EPA analysis of data from: Hunt, et al., *Resource and Environmental Profile Analysis*, 1974.

Employment Effects

The establishment of a returnable container system should result in increases in employment for the distribution and handling of containers. However, employment in the beverage container manufacturing industries would decrease due to reductions in the use of cans and nonrefillable bottles.

Employment estimates were made using quantitative relationships between employment levels and beverage container production and usage levels developed in previous studies. Employment impacts were estimated for the following seven industries:

- Soft drinks
- Malt liquor
- Wholesale beer distribution
- Retailing
- Glass container manufacturing
- Metal can manufacturing
- Metal suppliers

A nationwide deposit system would cause employment levels in the container manufacturing and supply industries to be decreased by 82,000 positions by 1980 compared with the baseline projection for that year (Table 30). However, employment levels in the beverage, beverage distribution, and retailing industries would be increased by over 164,000 positions, resulting in an overall net increase of 82,000 positions. This represents a 23-percent increase above the 1980 baseline projection.

The FEA and Commerce Department carried out similar analyses to derive employment impact estimates corresponding to the assumptions about container market shares and return rates used in those studies. The results of both these studies are broadly similar to those presented here in terms of both direction and general magnitude of change: (1) employment in the container manufacturing sector would be decreased by several tens of thousands, and (2) employment in other beverage supply and distribution sectors would be increased by several tens of thousands of jobs more than those lost in manufacturing.

Effects on labor income were estimated using average annual earnings of production workers in these industries. While the positions eliminated are generally higher paying than the positions gained, the increase in employment levels would result in a $400 million net increase in labor income in 1980 under a nationwide container deposit system (Table 31).

With regard to the decline in employment in the glass container, metal can, and primary metal manufacturing industries, of special concern are the *job dislocations* in those industries, or the number of individuals who would lose their jobs because of the shift in container use. It is important to note that the job dislocations are *less than* the difference in employment levels between the baseline and container deposit cases. Dislocations are reductions in the labor force employed prior to enactment of the deposit legislation and are therefore measured relative to the 1975 labor force. Furthermore, job losses due to productivity changes or normal employee attrition (resignations and retirements) must not be included in the count of dislocations caused by the change in container market shares.

TABLE 30

EMPLOYMENT LEVELS IN CONTAINER PRODUCTION AND USE[*]

(In thousands of jobs)

Year	Soft drink industry[†]	Malt liquor industry[†]	Wholesale beer distribution	Retailing	Glass container manufacturing	Metal can industries	Metal suppliers	Total
1975 baseline	102	19.8	56.2	13.4	36.5	42.0	22.8	293
1980 baseline	119	23.6	67.1	13.1	40.7	55.5	30.2	349
1980 deposit legislation	154	31.9	90.2	111.0	11.0	21.5	11.7	431
Net change (1980 deposit legislation minus 1980 baseline)	+ 35	+ 8.3	+23.1	+ 97.9	-29.7	-34.0	-18.5	+ 82

[*] EPA analysis of data from: Bingham, T. H., and P. F. Mulligan [Research Triangle Institute]. *The Beverage Container Problem; Analysis and Recommendations.* U.S. Environmental Protection Agency, Sept. 1972. 190 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-213 341); *Bottle Survey '71; A California Supermarket Report on the Cost of Handling Returnable Soft Drink Bottles.* La Habra, Calif., Alpha Beta Acme Markets, 1971. 16 p.; *Employment Dislocations Data.* Research Triangle Park, N. C., Research Triangle Institute, Apr. 10, 1974. 31 p.

[†] Container distribution employment only.

TABLE 31

LABOR INCOME FROM CONTAINER PRODUCTION AND USE*

(In millions of dollars)

Year	Soft drink industry[†]	Malt liquor industry[†]	Wholesale beer distribution	Retailing	Glass container manufacturing	Metal can manufacturing	Metal suppliers	Total
1975 baseline	745	257	517	99	347	479	269	2,710
1980 baseline	872	306	617	96	387	633	357	3,270
1980 deposit legislation	1,125	413	830	815	105	245	138	3,670
Net change (1980 deposit legislation minus 1980 baseline)	+ 253	+107	+213	+719	-282	-388	-219	+ 400

*EPA analysis of data from: Table 30; and U.S. Department of Labor, Bureau of Labor Statistics. *Employment and Earnings: United States 1909-1970*. Bulletin 1312-7. Washington, U.S. Government Printing Office, 1971. 602 p.

[†] Container distribution employment only.

It has been estimated that 43,000 employees would be affected by job dislocations resulting from a container deposit law that caused a gradual shift in container market shares over a 5-year period (Table 32). (In deriving this figure a 4-percent annual separation rate was applied to 1975 employment levels to account for normal employment attrition and productivity changes.) These job losses would be spread out over the 5-year transition period and would occur in proportion to the change in market mix of the different containers.* Depending on an area's existing unemployment rate and growth in other job opportunities, these job dislocations may represent significant hardships for affected employees and regions and are an important transitional social cost of the deposit legislation.

The dislocations will, in general, be spread out over many States, corresponding to the wide geographic distribution of container manufacturing plants, especially glass plants. While the economy should be readily able to absorb most of the displaced workers, there may be some areas where this is not the case. EPA's analysis has not attempted to identify specific areas that would have problems in this respect.

Industrial Investment Requirements

To the extent that container deposit legislation increases the market share of refillable bottles, new investments would be required in the soft-drink, malt liquor, wholesale beer distribution, and retail industries. In addition, future investment requirements for one-way containers and container systems would decline. It has been estimated that $1.8 billion in capital expenditures would be necessary to increase the market share of refillable bottles to 80 percent of the market at 1975 rates of consumption (Table 33)[†]. This includes costs of items such as transportation equipment, refillable bottle inventory, and new bottle-washing and filling lines. The estimates were derived by updating a 1969 beverage-industry-sponsored study of the investment requirements resulting from a ban on nonrefillable containers.

It is important that these figures not be interpreted as new or incremental capital expenditures for this industry. As the refillable bottle market share increases, the nonrefillable container share would decrease, as would investment requirements in that sector. Therefore, to some extent container deposit legislation merely causes a change from one type of capital purchase to another.

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*Longer transition periods would mean fewer job dislocations because employment reductions due to normal attrition and productivity improvements over the longer period would reduce the number of workers who would be affected. For example, a 10-year transition period would result in 24,000 job dislocations (13,700 in glass container manufacturing, 6,400 in the metal can industry, and 3,500 in the metal supply industry).

[†] The U.S. Department of Commerce has estimated investments of $3 to $5 billion for a 100-percent refillable bottle market based upon projections of the capital expenditures in Oregon after passage of deposit legislation.[2] The Federal Energy Administration has also estimated industry capital requirements for various refillable bottle market shares.[1]

TABLE 32

EMPLOYMENT DISLOCATION RESULTING FROM DEPOSIT LEGISLATION*

(Over a 5-year transition period)

Industry	Jobs
Glass container manufacturing	20,500
Metal can industry	14,400
Metal suppliers	7,800
Total	42,700

*EPA analysis of data of Table 30, using a 4 percent annual rate of employee separation to account for normal employment attrition.

Annual investments in the beverage and container industries in the 1970-75 period, based upon information provided by the U.S. Bureau of Census, are estimated at $600 to $800 million per year (Table 34). The major part of this investment was probably for capital expenditures for nonrefillable container systems, since such containers represented over 70 percent of the market and all growth was in that sector.

The above figures suggest that the annual investment requirements for increasing the refillable bottle share over a 5-year period would be of the same general magnitude as the current annual investment in one-way container systems. Therefore, a shift to refillable containers should not require significant incremental capital expenditures for the industry as an aggregate. However, certain segments of the industry, notably wholesale beer distribution and retailing, might have higher-than-normal investment levels.

TABLE 33

CAPITAL EXPENDITURES NEEDED TO INCREASE REFILLABLE BOTTLE MARKET SHARE AS PER DEPOSIT LEGISLATION SCENARIO*

Industry	Millions of dollars
Soft drinks	520
Malt liquor	760
Wholesale beer distribution	450
Retailing	50
Total	1,780

*EPA analysis of data from: Maillie, J., *The National Economic Impact of a Ban on Nonrefillable Beverage Containers: Final Report*. Kansas City, Mo., Midwest Research Institute, June 30, 1971. 120 p.

An estimate of the 1975 value of the capital stock that would be subject to accelerated depreciation due to container deposit legislation indicates $1.9 billion worth of capital and equipment would be written off over the 5-year transition period (Table 35). This estimate was derived by updating a 1969 beverage-industry-sponsored study of the accelerated capital writeoffs resulting from a ban on nonrefillable containers. It should be noted that the accelerated asset writeoffs do not represent a net cost to the affected industries since they also involve certain offsetting tax reductions. In order to estimate the effect on Federal tax revenues of such a writeoff, the accelerated depreciation schedule would have to be compared to the normal depreciation rate of such equipment.

TABLE 34

ANNUAL INVESTMENTS IN THE BEVERAGE AND CONTAINER INDUSTRIES, 1970-75*

Industry	Millions of dollars
Soft drinks	200 - 300
Malt liquor	160 - 200
Wholesale beer distribution	60 - 80
Glass container manufacturing	60 - 85
Metal can manufacturing	70 - 100
Metal suppliers	20 - 30
Total	570 - 815

*Personal communication. U.S. Bureau of Census to M. Loube, U.S. Environmental Protection Agency, May 1975.

Consumer Price Impacts

Numerous studies indicate that beer and soft drinks sold in refillable bottles are lower priced to the retail consumer than beverages in one-way bottles and cans.[9-13] Savings in the range of 3 to 8 cents per 12 ounces of beverage have frequently been observed. The savings are even greater for larger containers.

The prices are lower because refillable bottles used many times are much cheaper to a soft-drink bottler or brewer than one-way bottles and cans. This is true even though the use of refillable containers involves higher costs of filling, transportation, and storage as compared to one-way containers. The container cost savings more than offset the higher handling costs.

TABLE 35

CAPITAL STOCK THAT WOULD UNDERGO ACCELERATED DEPRECIATION DUE TO DEPOSIT LEGISLATION*

Industry	Millions of dollars
Soft drinks	272
Malt liquor	254
Glass container manufacturing	113
Metal can manufacturing	813
Metal suppliers	450
Total	1,915

*EPA analysis of data from: Maillie, *The National Economic Impact*, 1971.

A shift to refillable bottles caused by deposit legislation would involve some changeover costs that are not reflected in present-day prices. Therefore, in the early years of the transition, the average prices might be higher than the price for beverages in refillable bottles today. However, there is no reason to believe that prices would be higher than those currently charged for beverages in one-way containers. In the longer term, with container deposits average consumer prices for beer and soft drinks should be less.

In order to estimate national consumer cost savings from a transition to returnable containers, it was assumed that retail prices for beverages in refillable bottles would be 2.5 cents cheaper per container than beverages in one-way glass bottles and 5 cents cheaper than beverages in metal cans. This is a conservative assumption based upon current price differentials. Future retail price differentials could widen since the cost of metal cans has been increasing faster than the cost of glass bottles. Annual consumer savings would total $2.5 billion by 1980 and $3.2 billion by 1985, with cumulative savings through those years of $7 billion and $22 billion, respectively (Table 36). The Federal Energy Administration study estimated similar reductions in consumer expenditures of $1.8 to $2.6 billion annually by 1982.[1]

CONCLUSIONS

The results of EPA analyses indicate that Federal beverage container deposit legislation would cause a significant shift in beverage container systems towards reuse and recycling. Most analysts predict a very significant decrease in nonrefillable bottles and a less significant decrease in the use of metal cans.

TABLE 36

CONSUMER SAVINGS RESULTING FROM CONTAINER DEPOSIT LEGISLATION*

(In billions of dollars)

Year	Annual savings	Cumulative savings through the year
1980	2.5	7.0
1985	3.2	22.0

*EPA analysis using data from References 8 through 12.

An analysis of the projected container market response and its effects, based on relatively extreme but not unreasonable assumptions regarding shifts in container mix, return rate, and can recycle rates, yields the following conclusions:

Environmental and resource conservation effects:

- Reduction in roadside litter by 60 to 70 percent of container litter and 20 to 40 percent of total litter.
- Reduction in annual municipal solid waste of about 7 million tons (1980), or 5 percent of total waste (including food and yard waste) or 8.5 percent of the manufactured goods portion of solid waste.
- Reductions in U.S. total energy consumption by 1980 of over 245 trillion Btu, or about 40 percent of total energy required to supply beer and soft drinks.
- Annual virgin raw material savings of 5.2 million tons of glass, 1.5 million tons of steel, 500,000 tons of aluminum, and many hundreds of thousands of tons of auxiliary materials (limestone, sodium carbonate, etc.) by 1980.

Economic impacts:

- The total economic cost of supplying beverages would most likely be less—a national economic saving of about $2.5 billion per year at projected 1980 consumption rates.
- Consumer prices would be lower by about 2.5 cents per 12-oz. serving.
- Consumer "convenience" would be reduced by the returning of containers.
- Total employment would be higher, on a net basis, by approximately 80,000 jobs (1980).

- Container manufacturing employment would be decreased by about 80,000 positions; about one-half of the decrease would be in the form of actual layoffs of employed workers and half would occur through normal attrition over a 5-year transition period. This could cause some significant regional hardships.
- Employment in the beverage supply, distribution, and retailing sectors would be increased by about 165,000 jobs by 1980.
- Overall total national investment requirements would not be significantly changed. There would be a major shift in investment away from container manufacture and towards container filling and distribution, especially in the transition period. Long-term investment requirements could be reduced.

REFERENCES

1. Research Triangle Institute. Energy and economic impacts of mandatory deposits; final report. Federal Energy Administration, Sept. 1976. 752 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-258 638.)
2. The impacts of national beverage container legislation. Staff Study A-01-75. Washington, U.S. Department of Commerce, Bureau of Domestic Commerce, Oct. 1, 1975. 20 p. (Unpublished report.)
3. Bingham, T. H., and P. F. Mulligan [Research Triangle Institute]. The beverage container problem; analysis and recommendations. U.S. Environmental Protection Agency, Sept. 1972. 190 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-213 341.)
4. Nuss, G. R., et al. [Midwest Research Institute]. Base line forecasts of resource recovery, 1972 to 1990: final report. Environmental Protection Publication SW-107c. U.S. Environmental Protection Agency, 1975. 386 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-245 924.)
5. Applied Decision Systems, and Decision Making Information, Inc. Study of the effectiveness and impact of the Oregon minimum deposit law; project completion report. Salem, State of Oregon Department of Transportation, Highway Division, Oct. 1974. 1 v. (various pagings).
6. Waggoner, D. Oregon's bottle bill two years later. Portland, Columbia Group Press, May 1974. 37 p., app.
7. Loube, M. Beverage containers: the Vermont experience. Environmental Protection Publication SW-139. [Washington], U.S. Environmental Protection Agency, 1975. 16 p.
8. Hunt, R. G., et al. [Midwest Research Institute]. Resource and environmental profile analysis of nine beverage container alternatives; final report. v. 1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p.
9. No deposit, no return; a report on beverage containers. Albany, New York State Senate Task Force on Critical Problems, Feb. 1975. 106 p., app.
10. Stern, C., et al. Impacts of beverage container legislation on Connecticut and a review of the experience in Oregon, Vermont and Washington State. Storrs, University of Connecticut, Department of Agricultural Economics, Mar. 20, 1975. 181 p.
11. Impacts of beverage container regulations in Minnesota; a report to the Governor and the Minnesota Legislature. [Minneapolis], Minnesota State Planning Agency, Jan. 1974. 140 p.
12. Statement of J. Lucian Smith, President, Coca-Cola, U.S.A. *In* U.S. Congress, Senate, Committee on the Judiciary. Exclusive territorial allocation legislation. Hearings before the Subcommittee on Antitrust and Monopoly, 92d Cong., 2d sess., on S. 3040, S.3116, S.3133, S.3145 and S.3587. pt. 1. Aug. 8-10, Sept. 12 and 14, 1972. Washington, U.S. Government Printing Office, 1973. p. 161-194.
13. Peterson, C. Price comparison survey of beer and soft drinks in refillable and non-refillable containers. Washington, U.S. Environmental Protection Agency, 1976. [9 p.], app.

Appendix A

DESCRIPTION AND STATUS OF EPA-SUPPORTED RESOURCE RECOVERY TECHNOLOGY DEMONSTRATION PROJECTS

The actual technical and economic feasibility of "high-technology" resource recovery systems can be ascertained only if the systems are demonstrated at operational scale. However, the high capital costs and the technological and economic risks involved naturally make it difficult for cities to undertake constructing the first prototypes of such systems. The EPA program of demonstration grants enables cities to implement promising systems by assuming part of the risks.

Problems in the planning, construction, and operation of these facilities were expected as a normal part of technology development. The demonstration program is intended to address the problems which emerge in this stage of development and ultimately result in technologies that are feasible and can be quickly replicated. The information developed from these projects can thus guide cities in their decisions on emerging resource recovery systems.

Two of EPA's resource recovery demonstration projects, those located at St. Louis and Franklin (Ohio), are now essentially complete. The technical results and economic projections from these demonstrations were sufficiently encouraging so that both technologies are now being replicated in commercial resource recovery plants. These plants will serve to further define technical and economic feasibility. Of the more recently funded demonstrations, the one in Baltimore has exhibited scale-up problems that have required significant modifications that are now underway. Two other projects, in San Diego and Delaware, have experienced delays and, in San Diego, significant cost increases. The delays were primarily due to the kind of "institutional" problems that have delayed numerous resource recovery installations.

While the major emphasis of the demonstration program has been on large processing facilities that recover resources from mixed solid waste, other forms of recovery are also being developed. A demonstration of the recovery of methane from a sanitary landfill is being conducted in Mountain View, California. The initial testing and design studies indicated the feasibility of recovering the gas, treating it to raise the Btu content, and injecting it into a nearby pipeline. A full-scale demonstration system is now being installed.

Demonstrations of multimaterial source separation and separate municipal collection have been operational for a few months in Somerville and Marblehead, Massachusetts. The early results have been encouraging.

Overall, the EPA demonstration program has produced several benefits. Testing and evaluation of the demonstration projects have greatly increased the amount of available data, although more data are necessary. The experience of users of recovered energy and materials will be helpful in setting marketing specifications. System builders and operators have also acquired valuable waste-handling experience. And the development of a new and important industry has been stimulated.

The demonstrations have served to illustrate that resource recovery is neither a panacea nor an impossible dream. It can provide an opportunity to reduce disposal requirements and to conserve resources at a reasonable cost, although there are still significant technological and economic risks at the current stage of development. Such risks can be reduced only by acquiring more information through the evaluation of demonstration and operational systems.

The following describes the eight projects supported by EPA. The costs, schedules, participants, and plant outputs are summarized for each project in the tables.

FRANKLIN, OHIO (Tables A1 and A2)

Background. In March 1969, EPA awarded a grant to Franklin, Ohio, to demonstrate the recovery of materials by a wet processing system. This was the first such demonstration grant awarded by EPA, and the project was completed in March 1976. The project was initially designed to determine the feasibility of wet processing and fiber recovery. Later it was expanded to include the demonstration of aluminum recovery and color-sorting glass.

System Description. The Franklin system is a wet pulping process and associated fiber reclamation subsystem designed by the Black Clawson Company. Solid waste is mixed with water and pulped in a hydrapulper; this works on a principle similar to that of a kitchen blender and was adapted from equipment used in the paper industry. Fibrous material from the hydrapulper is screened and washed to produce paper fiber. Reject fiber is mixed with sewage sludge from a neighboring wastewater treatment plant and burned in a fluid bed incinerator. Acceptable fibers are pumped as a slurry to a neighboring roofing felt mill. Metals and glass from the hydrapulper are also recoverable. Ferrous metals are extracted magnetically. Other metals and glass are sent through a series of screening and classifying operations to produce an aluminum-rich and glass-rich stream. In this subsystem, which has been operating primarily on a test basis, there is also equipment to separate clear glass from colored glass with an optical sorter. The capacity of the Franklin plant is 150 tons of solid waste in a 24-hour day.

Operating Results

- The plant has operated continuously since 1971, processing an average of 35 tons per day of Franklin's solid waste at a throughput rate of about 7 tons per hour. The plant has never turned away waste due to overload or equipment failure.

TABLE A1

TIME AND COST SCHEDULE, FRANKLIN PROJECT

Phase and activity	Time period	Total cost*†	Federal share of cost
Hydrasposal and Fiber Recovery Systems:			
Design	March 1969 to February 1970	$ 165,000	$ 110,000
Construction	March 1970 to June 1971	1,970,000	1,300,000
Operation and evaluation	June 1971 to September 1974	500,000	350,000
Subtotal		2,635,000	1,760,000
Glass and Aluminum Recovery System:			
Design	June 1971 to May 1972	20,000	15,000
Construction	May 1972 to July 1973	360,000	232,000
Operation and evaluation	July 1973 to March 1976	90,000	147,000
Subtotal		470,000	394,000
Total		$3,105,000	$2,154,000

*Approximate non-Federal contributions: the city of Franklin, $500,000; the Black Clawson Company, $268,500; and the Glass Packaging Institute, $181,500.

†Does not include costs to evaluate the overall plant performance under a separate EPA contract.

TABLE A2
PRODUCTS AND MARKET VALUES, FRANKLIN PROJECT

Product	Tons per 100 tons of waste input	Approximate market price received (per ton)
Ferrous metal	9	$ 25
Paper fiber	20*	10 – 60
Glass (color-sorted)	3	†
Aluminum	0.3	†

*Dry weight basis of input and output.
†Market values uncertain; outputs not sold regularly.

- Under best operating conditions, 49 percent of the incoming paper is recovered and sold for use in making felt roofing shingles; 94 percent of the ferrous metals are recovered and sold to the steel industry.
- Up to 60 percent of the incoming glass can be recovered as a color-sorted product. Although separation of clear and colored glass has been acceptable, the process has not been able to produce a product with sufficiently low levels of refractory contaminants to meet market specifications.
- The aluminum product recovered is not being cleaned or refined, but is marketable and may be upgraded for increased market value.
- Exhaust gases from the fluidized bed incinerator meet applicable State and Federal standards.
- Water from the process is treated in the neighboring wastewater treatment plant.

While the pulping and fiber recovery system has been operated as the primary means of waste disposal for Franklin, with the products sold regularly, the glass/aluminum recovery subsystem has been operated as an experimental system by the Black Clawson Company, the Glass Packaging Institute, and EPA.

Prospects for the Future. The Franklin demonstration has proven the feasibility of wet processing solid waste to produce a low-quality fiber. In cost projections of larger plants with nearby users of low-grade fiber, the process appears to be economically viable. However, since the markets for this low-quality fiber are limited, later versions of this plant may emphasize recovery of fiber for use as a fuel. The town of Hempstead, New York, has signed a contract with the Hempstead Resource Recovery Corporation (subsidiary of the Black Clawson Company) to build a wet pulping system to produce a fuel for on-site burning to generate electricity.

A first step in the difficult problem of recovering color-sorted glass has been demonstrated. However, the marketability of the recovered glass products, with its present level of refractory contamination, and the economic feasibility of glass recovery are questionable.

ST. LOUIS, MISSOURI (Table A3)

Background. The St. Louis project, now completed, began in 1970 on the recommendations of a feasibility study sponsored by EPA. In July 1970, EPA awarded a grant to the city of St. Louis to demonstrate the feasibility of burning shredded municipal solid waste in an existing utility boiler as a supplement to pulverized coal. The plant began operating in 1972 and continued intermittently through 1976.

System Description. At a processing plant, commercial and residential waste are shredded to a 1½-inch particle size. The shredded material is then air classified into two fractions. The heavy fraction is processed to recover ferrous metals. The residue of this fraction is landfilled.

The light fraction (refuse-derived fuel, or RDF), which has a heat value of about one-half that of coal, is transported by truck to the Union Electric Com-

TABLE A3

TIME AND COST SCHEDULE, ST. LOUIS PROJECT

Activity	Time period	Total cost	Federal share of cost
Design and construction	July 1970 to August 1972	$3,288,544	$2,180,026
Operation and evaluation	May 1972 to June 1975	600,000	400,000
Total		$3,888,544*	$2,580,026

*Union Electric Company provided $950,000 and the city of St. Louis the remaining $358,518 of the non-Federal share. In addition, EPA spent over $1 million to evaluate the project.

pany's Meramec Power Station where it is used to supplement coal in an existing pulverized-coal-fired, steam-electric boiler. At St. Louis, about 80 to 85 percent of the input to the air classifier has been recovered as RDF.

Operating Results. Most of the equipment at the processing plant performed essentially as designed. However, the system had a low reliability because it was designed as simply and cheaply as possible, with no redundancy. The plant was operated intermittently, more as a test facility than a commercially operating RDF production plant.

The project showed that the RDF produced could be fired at boiler heat input rates of from 5 to 27 percent without noticeable adverse boiler operation effects. Although corrosion of boiler tubes is frequently cited as a concern, Union Electric indicates that they have not observed an increase in short-term corrosion.

Handling the shredded waste was more difficult than originally anticipated. Several pieces of equipment were modified to improve handling.

Environmental testing has been conducted at both the processing plant and the powerplant. At the processing plant it was determined that dust from several pieces of equipment should have been controlled (as it will be in second-generation plants). Additional testing to look more closely at dust and airborne bacteria and viruses associated with handling solid waste was completed in November 1976. The results will be available in the summer of 1977.

Tests of particulate emissions were not totally conclusive. There was considerable data scatter. Also different series of tests were conducted over a 2-year period, thus changes in boiler operations and electrostatic precipitator (ESP) collection efficiency could have influenced results. The tests indicated no change in uncontrolled particulate emissions with combined firing of waste and coal. However, controlled emissions were found to increase at boiler loads at or above the boiler's nominal design capacity. The increase in controlled emissions was attributed to a decrease in the collection efficiency of the ESP when solid waste was burned. The efficiency loss in turn was attributed to higher gas flow rates through the precipitator when refuse was burned. Higher gas flow rates were expected due to the conversion of moisture in the RDF to steam upon combustion. Though the increased gas flow concept is strongly supported by air pollution experts as an expected phenomenon and probable cause of the efficiency loss in the ESP, measurements of gas flow rates did not clearly confirm the increase. Also contrary to expectation was the finding that emissions did not increase as the percentage of RDF fired was increased.

Obviously, additional testing at other facilities will be needed to provide more complete data on air emissions when burning solid waste in combination with coal. This would be necessary in any case since other boiler/precipitator combinations, RDF characteristics, and coal types would be expected to yield different results.

Prospects for the Future. Although the unit operations have not been optimized to perform continuously at lowest cost, the demonstration proved that solid waste could be processed to produce a fuel which could be fired in suspension with pulverized coal in an existing steam-electric boiler without significant adverse short-term boiler operation effects. Nevertheless, many questions regarding combined firing with coal have not been adequately answered, and utilities are understandably cautious about use of this new fuel.

A number of commercial systems of this type have resulted from this demonstration. One of these, in Ames, Iowa, is already in operation. Systems in Milwaukee and Chicago are under construction and should be operating by early 1977. In addition, similar systems are planned in Bridgeport, Connecticut, and Monroe County, New York, and are under consideration in numerous other communities.

BALTIMORE, MARYLAND (Table A4)

Background. In September 1972, EPA awarded a grant to the city of Baltimore to demonstrate the generation of steam through pyrolysis using a process developed by the Monsanto Company. Pyrolysis is the physical and chemical decomposition of organic matter brought about by the action of heat in an oxygen-deficient atmosphere.

System Description. The Baltimore "Landgard" plant was developed by Monsanto Enviro-Chem Systems, Inc., with a capacity of 1,000 tons per day. Plant design calls for solid waste to be shredded and fed into a pyrolysis kiln. Inside the kiln, temperatures to about 2,600° F pyrolyze the organic portion of the waste into a gas.

The pyrolytic gases are burned in an afterburner, and the resulting hot gases flow through two waste-heat boilers. For 100 tons of waste input, approximately 180 tons of steam is produced; the market value of the steam is about $5.50 a ton. The Baltimore Gas and Electric Company is using the steam for a downtown steam loop.

The residue from the kiln was to be separated into three fractions: ferrous metals, char, and a glassy aggregate. Due to operational problems, however, the residue separation subsystem has functioned in a test mode for only a few hours.

TABLE A4

TIME AND COST SCHEDULE, BALTIMORE PROJECT

Activity	Time period	Total cost*	Federal share of cost
Design and construction	January 1973 to December 1974	$16,300,000	$6,000,000
Shakedown	January 1975 to September 1975		
Modification	January 1976 to October 1977	5,000,000	1,000,000
Installation of emissions controls	August 1977 to February 1979	5,000,000	
Evaluation	October 1976 to April 1978	350,000	200,000
Total		$26,650,000	$7,200,000

*Maryland Environmental Services provided $4 million; Monsanto Enviro-Chem Systems provided $4 million; and Baltimore will provide $10.95 million of the non-Federal share.

Operating Results. Construction of this facility was completed in early 1975. Shakedown testing began shortly thereafter, and after a few months of intermittent running it became apparent that the plant could not meet two of the performance guarantees: guaranteed throughput of 51,000 tons of solid waste in a 60-day period, and emissions to the atmosphere of less than 0.03 grains of particulate per dry standard cubic foot of undiluted exhaust gas (the State standard).

Monsanto, the system designer, traced the high emission levels of the demonstration plant to the presence of a greater number of submicron particles than were produced in the pilot plant. (Submicron particles are more difficult to collect than larger particles.) Monsanto believed that the high level of submicron particles was caused by sublimation, or vaporization, and condensation of certain inorganic salts during the pyrolysis reaction. This phenomenon did not occur in the pilot plant. In scaling up from 35 to 1,000 tons per day, key design and operating parameters (equipment size, temperatures, residence time of solid waste in the kiln, etc.) were increased in certain proportions. The difference in performance between the demonstration plant and the pilot plant appears to have been caused by incorrect scaling of some parameters. Many of the mechanical problems that are limiting the throughput are also a result of scale-up difficulties. This situation illustrates the risk inherent in scaling up technology from pilot to commercial scale.

When the problems were first encountered, Monsanto tried various process adjustments, but they were unable to duplicate the low level of emissions experienced in the prototype. Three air pollution control devices were tested; one of these, an electrostatic precipitator, was found capable of controlling the emissions to meet the State standard and will be installed.

A supplemental agreement between the city and Monsanto was signed on December 31, 1975. Funds for the work outlined in this agreement will be $4 million contributed by Monsanto (equivalent in amount to the original performance guarantee) plus an increase in the EPA grant of $1 million. This work covered mechanical modifications that were to improve the reliability of the system and enable the plant to have a daily throughput of about 75 percent of design capacity.

The procurement, installation, and shakedown of the air pollution control equipment was not part of the supplemental agreement. The device will be purchased by the city after positive assurance that the plant will operate effectively.

The total estimated cost of all the work required, including the new air pollution control device, is between $8 and $12 million.

Prospects for the Future. The Baltimore plant has had significant operating problems. In February 1977, after unsuccessful attempts at 30-day performance runs, Monsanto recommended that the plant be shut down. Reasons stated were their inability to predict clearcut success and continued mechanical problems. The city refused to accept Monsanto's recommendation, terminated the supplemental agreement, and is continuing with the project. After three scheduled 30-day runs this spring, the city will decide to continue with the project or convert the facility into a more conventional solid waste facility. Based on the total capital cost of about $27 million currently estimated at Baltimore, and the steam revenues expected in Baltimore, the system is projected to be economically competitive with most other disposal and recovery alternatives. The problems at Baltimore must first be resolved, however.

SAN DIEGO COUNTY, CALIFORNIA
(Tables A5 and A6)

Background. In September 1972, EPA awarded a grant to San Diego County to produce a liquid fuel from municipal solid waste through a process of pyrolysis developed by the Occidental Research Corporation (formerly Garrett Research and Development Company), a subsidiary of Occidental Petroleum Corporation. The primary product of the process is an oil-like liquid with a heating value of about 60 percent that of No. 6 heating oil on a volumetric basis. The "oil" is to be burned as a supplement to fuel oil in the electric utility boilers of the San Diego Gas and Electric Company. Ferrous metal, aluminum, and mixed glass cullet will also be recovered.

Groundbreaking ceremonies were conducted in August 1975 and construction was completed in December 1976. The facility is expected to begin operating in June 1977 for a 1-year test period.

Original project costs for construction, operation,

TABLE A5

TIME AND COST SCHEDULE, SAN DIEGO PROJECT

Activity	Time period	Total cost*	Federal share of cost
Design	December 1974 to April 1975	$11,233,000	$4,262,710
Construction	August 1975 to December 1976		
Operation and evaluation	June 1977 to May 1978	2,364,000	
Total		$13,597,000	$4,262,710

*San Diego County is to provide $2 million, and Occidental Research Corporation is to provide the remainder of the non-Federal share.

TABLE A6

ANTICIPATED OUTPUTS AND PRICES, SAN DIEGO PROJECT

Product	Quantity per 100 tons waste input	Approximate market value
Oil	100 barrels	$ 2.30 per barrel*
Ferrous metal	6.7 tons	34.00 per ton
Glass	5.3 tons	16.00 per ton
Aluminum	0.4 tons	260.00 per ton

*Currently being renegotiated.

and evaluation were estimated at $4 million, but they have escalated to $13.6 million. Inflation was, of course, one factor. Other factors that have increased costs include: (1) change of the plant site and, as a result, modifications of the design; (2) additional odor control equipment; (3) the addition of an aluminum recovery subsystem; (4) additional redundance and landscaping.

It is anticipated that net operating costs at San Diego will also be high. Although scale-up is significant (from 4 tons per day to 200 tons per day), the planned size is not considered large enough to be economical. However, it is large enough to predict performance at commercial scale.

System Description. Incoming waste will be shredded and air classified. Ferrous metal, aluminum, and glass (froth-floated) will be recovered from the heavy fraction. The light fraction, after additional shredding to reduce the particles to a very fine size (consistency of vacuum cleaner fluff), will go to the pyrolysis reactor. A flash reaction (short retention time) produces gases that are then condensed rapidly to produce the oil. The reaction occurs at relatively low temperatures of about 900°F.

Testing and Evaluation. Once the plant is finished, a complete technical, economic, and environmental evaluation program will be conducted. Testing will be split between the processing plant, where the waste is converted to liquid fuel, and the powerplant, where it is burned along with No. 6 fuel oil to produce electricity. The testing program is scheduled to last 1 year, beginning May 1977, after 3 months of shakedown.

Because of the unique meteorological and geographic characteristics of the site, it will also be necessary to monitor the impact of the processing plant on ambient nitrogen oxide levels. It has been predicted that under certain infrequent adverse weather conditions, nitrogen oxide levels in the vicinity of the plant might exceed allowable levels established by San Diego County. If this occurs, it may be necessary to suspend operations at the plant periodically for a few days at a time.

Prospects for the Future. Because the fuel produced by this process is liquid, it is expected to have two advantages over other energy forms produced from solid waste: it is both storable and transportable. This means that the processing facility and the user need not be close and that their operating schedules need not be the same. However, it remains to be seen whether the fuel can be produced in a technically reliable and cost-effective manner.

STATE OF DELAWARE (Tables A7 and A8)

Background. In October 1972, EPA awarded a grant to the State of Delaware for a process that will produce RDF for use as a supplement to fuel oil in an existing oil-fired, steam-electric boiler. In addition, the project will handle digested sewage sludge, produce humus by composting, and recover ferrous metals, aluminum, and glass.

The planned plant capacity is 500 tons per day of municipal solid waste and 230 tons of digested sewage sludge (8 percent solids).

Current Status. Based on proposals received in December 1976, the State solid waste authority began negotiating with the Raytheon Service Company in April 1977 for the design, construction, and operation of the facility.

TABLE A8

ANTICIPATED OUTPUTS AND MARKET VALUES, DELAWARE PROJECT*

Product	Tons per day†	Market value per ton sold
Humus (compost)	38 (dry)	$ 14.70
Solid waste fuel	305	16.40†
Ferrous metal	35.5	40.00‡
Nonferrous metal	2	200.00
Glass	25	7.00
Paper	5	10.00
Sludge disposal	18 (dry)	40.00

*Estimates by EPA based on earlier estimates by Black, Crow and Eidsness, Inc., for the State of Delaware.

†Based on input of 500 tons per day of solid waste (wet weight).

‡Assumes fuel oil costs $2.00 million per Btu, and that solid waste fuel has a heat value of 5,000 Btu/lb, or 10 million Btu/ton. Value of fuel is discounted to reflect the boiler efficiency loss when firing waste. Efficiency loss is assumed to be 2 percent.

SOMERVILLE AND MARBLEHEAD, MASSACHUSETTS (Tables A9 and A10)

Background. Two Massachusetts communities, Somerville and Marblehead, have been awarded grants by the EPA to demonstrate the feasibility of weekly curbside collection of paper, glass, and cans using a compartmentalized collection truck. Somerville is a densely populated urban community, with no history of recycling activities. Marblehead is a suburban bedroom community that has been recycling on a townwide basis for 3 years.

System Description. Ordinances passed by the two communities mandate that citizens separate their refuse into several categories. In Somerville, the categories are paper; glass and cans; and all other waste. In Marblehead, the glass-and-cans fraction is segregated into (1) clear glass and cans and (2) brown and green glass and cans. The paper, glass, and cans are

TABLE A7

TIME AND COST SCHEDULE, DELAWARE PROJECT

Activity	Time period	Total cost	Federal share of cost
Design and construction	October 1977 to October 1980	$25,000,000	$6,755,000
Startup	October 1980 to July 1981	328,000	245,000
Operation and evaluation	July 1981 to July 1982	2,700,000	2,000,000
Total		$28,028,000	$9,000,000

TABLE A9

TIME AND COST SCHEDULE, SOMERVILLE AND MARBLEHEAD

Activity	Time period	Total cost	Federal share of cost
Somerville:			
Capital expenditures		$ 41,000	$ 41,000
Planning, operation, and evaluation	July 1975 to June 1979	308,000	84,000
Total		$349,000	$125,000
Marblehead:			
Capital expenditures		$ 40,000	$ 40,000
Planning, operation, and evaluation	July 1975 to June 1979	212,000	41,000
Total		$252,000	$ 81,000

TABLE A10

PRODUCTS AND MARKET VALUES, SOMERVILLE AND MARBLEHEAD*

Product	Tons per 100 tons of waste generated	Market price received (per ton)†
Somerville:		
Paper	5	$ 6-21
Glass	2	10
Cans	0.5	5-27
Marblehead:		
Paper	13.5	12-27
Glass	11.6	12
Cans	3.0	10-29

*These are actual data based on 3 months of operation.
†Floating prices based on market indexes.

collected weekly in a newly designed compartmentalized vehicle. Mixed waste is collected weekly in a regular collection truck. The recovered materials are sold to a processor under a contract with a guaranteed floor price that was negotiated through an open bidding procedure before the programs started. The processor mechanically separates the glass, ferrous metals, and aluminum, and bales the paper for resale to manufacturers.

The programs, which began in Somerville on December 1, 1975, and in Marblehead on January 19, 1976, were preceded by extensive publicity and public education campaigns that included the cooperation of citizen groups and schools. Publicity is projected to continue for the life of the program. During the initial months, Marblehead recovered 23 to 33 percent of their residential solid waste and Somerville recovered 7 to 10 percent. The Marblehead program is making a profit; Somerville is breaking even.

Prospects for the Future. The Marblehead/Somerville projects will take a major step toward determining the feasibility of source separation and combined separate collection of paper, metals, and glass. Historically, fluctuating prices for secondary materials and the lack of efficient collection systems have hindered efforts to maintain viable communitywide separate collection programs. New techniques for separate collection and an increased interest on the part of industry to engage in long-term contracts for the purchase of recovered materials will increase the economic feasibility of source separation, and this form of resource recovery may become an attractive alternative or complement to landfilling or high-technology resource recovery systems.

(See Chapter 4 for further details of the Marblehead and Somerville programs.)

MOUNTAIN VIEW, CALIFORNIA (Table A11)

Background. In June 1974, EPA awarded a grant to the City of Mountain View, California, to demonstrate the recovery of methane from a sanitary landfill. The objectives of the project were to determine (1) the composition of the gas produced by the landfill; (2) the optimum rate of gas withdrawal and spacing of wells; (3) the site's potential rate of gas production; and (4) the effect on gas production of varying the solid waste moisture content.

The Pacific Gas and Electric Company agreed to provide laboratory facilities for gas analysis and to evaluate the various methods of using the gas.

System Description. The 250-acre site at Mountain View was selected in order to determine the feasibility of methane recovery from a typical shallow (40-foot deep) sanitary landfill. A three-phase program was developed for the initial study.

Phase 1 ascertained the effect of the gas withdrawal rate on gas composition and the optimal withdrawal rate for long-term pumping. This was accomplished through the installation and operation of several production wells and numerous monitoring wells.

Phase 2 was intended to determine the potential rate of gas production, potential revenues, and estimated production costs. This information was needed to assess the desirability of further site development.

Phase 3 consisted of an evaluation of the effect of moisture content on gas production. A water distribution grid was installed around one production well to saturate the refuse with moisture. A similar well, lacking the water distribution system, was used as a control. Both wells were pumped at the optimal rate, as determined in Phase 1, while gas qualities were compared to determine the effect of the moisture.

Operating Results. Testing of prototype production wells began in December 1974. These wells were constructed in two levels, one extending from the surface to the middle of the landfill, and the other continuing to the bottom. Test results indicated that atmospheric interference was inversely proportional to well depth. As air was drawn into the upper level, the decomposition rate, and therefore methane production, was negatively affected.

An examination of withdrawal rates determined that a rate of no greater than 50 cubic feet per minute (cfm) per well would maintain a steady, optimal gas composition of approximately 44 percent methane, 34 percent carbon dioxide, and 20 percent nitrogen. At higher withdrawal rates, concentration of methane fell and that of nitrogen increased as air entered the fill.

The well being pumped at the optimal rate was determined to have a radius of influence of 130 feet. Using overlapping radii, the calculated withdrawal rate is .039 million cubic feet per acre per day. Thus, with an effective surface area of 150 acres of landfill, the site could theoretically produce 5.8 million cubic feet of gas per day with a 44 percent methane content.

An evaluation by the Pacific Gas and Electric Company indicated that using the gas for electrical

TABLE A11

TIME AND COST SCHEDULE, MOUNTAIN VIEW, CALIFORNIA

Activity	Time period	Total cost*	Federal share of cost
Testing and design studies	July 1974 to July 1975	$ 60,000	$ 60,000
Full-scale implementation	July 1975 to May 1978	617,000	200,000
Total		$677,000	$260,000

*Pacific Gas and Electric Company is providing the $417,000 non-Federal share.

generation, conversion to methanol, or production of pipeline quality gas is economically unfeasible. While direct, interruptible use of the treated or untreated gas by customers near the site appeared to be the most economical solution, a suitable user could not be found. Injection of untreated gas into PG&E's network would lower the quality of the pipeline gas to an unacceptably low level, but treatment could raise the gas from 500 Btu/scf to 700 Btu/scf, allowing injection into a nearby pipeline without significantly decreasing the quality of the pipeline gas.

Due to problems with the third phase of the test program, the evaluation of moisture effects on the rate of gas production was not completed.

Prospects for the Future. The success of the first two phases of the test program has resulted in plans for a full-scale gas recovery program. Mountain View was awarded an additional $200,000 in November 1975, and PG&E has agreed to provide an additional $400,000 to design, install, and operate a molecular sieve gas treatment plant with a capacity of 1 million cubic feet per day. The plant will upgrade the Btu content of the gas, which will be supplied by 20 wells producing gas at a rate of 40 to 50 cfm each. The entire system will be operational by July 1977.

BIBLIOGRAPHY ON EPA DEMONSTRATION PROJECTS

Arella, D. G. Recovering resources from solid waste using wet-processing; EPA's Franklin, Ohio, demonstration project. Environmental Protection Publication SW-47d. Washington, U.S. Government Printing Office, 1974. 26 p.

Hansen, P., and J. Ramsey. Demonstrating multimaterial source separation in Somerville and Marblehead, Massachusetts. *Waste Age*, 7(2):26-27, 48, Feb. 1976.

Garbe, Y. M. Color sorting waste glass at Franklin, Ohio. *Waste Age*, 7(9):70-71, Sept. 1976.

Garbe, Y. M. Demonstration of pyrolysis and materials recovery in San Diego, California. *Waste Age*, Dec. 1976. (In press.)

Holloway, J. R. Resource recovery technology update from the U.S.E.P.A.: EPA resource recovery demonstration: summary of air emissions analyses. *Waste Age*, 7(8):50-52, Aug. 1976.

Horner & Shifrin, Inc. Solid waste as fuel for power plants. Environmental Protection Publication SW-36d. U.S. Environmental Protection Agency, 1973. 146 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-220 316.)

Levy, S. J. San Diego County demonstrates pyrolysis of solid waste to recover liquid fuel, metals, and glass. Environmental Protection Publication SW-80d.2. Washington, U.S. Government Printing Office, 1975. 27 p.

Lowe, R. A. Energy recovery from waste; solid waste as supplementary fuel in power plant boilers. Environmental Protection Publication SW-36d.ii. Washington, U.S. Government Printing Office, 1973. 24 p.

Roberts, R. M., et al. [Envirogenics Company]. Systems evaluation of refuse as a low sulfur fuel. Washington, U.S. Environmental Protection Agency, 1971. 2 v. (Distributed by National Technical Information Service, Springfield, Va., as PB-209 271 – PB-209 272.)

SCS Engineers. Analysis of source separate collection of recyclable solid waste; separate collection studies. [v. 1.] Environmental Protection Publication SW-95c.1. U.S. Environmental Protection Agency, 1974. [157 p.] (Distributed by National Technical Information Service, Springfield, Va., as PB-239 775.)

SCS Engineers. Analysis of source separate collection of recyclable solid waste; collection center studies. [v.2.] Environmental Protection Publication SW-95c.2. U.S. Environmental Protection Agency, 1974. [75 p.] (Distributed by National Technical Information Service, Springfield, Va., as PB-239 776.)

Shannon, L. J., D. E. Fiscus, and P. G. Gorman [Midwest Research Institute, Inc.]. St. Louis refuse processing plant: equipment, facility and environmental evaluations; final report, Sept. 1974 – Jan. 1975. Washington, U.S. Environmental Protection Agency, May 1975. 122 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-243 634.)

Shannon, L. J. et al. [Midwest Research Institute, Inc.]. *St. Louis/Union Electric refuse firing demonstration air pollution test report.* Washington, U.S. Environmental Protection Agency, Aug. 1974. 107 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-237 630.)

Sussman, D. B. Baltimore demonstrates gas pyrolysis; resource recovery from solid waste. Environmental Protection Publication SW-75d.i. Washington, U.S. Government Printing Office, 1975. 24 p.

[Sussman, D. B.] Resource recovery technology update from the U.S.E.P.A.; Baltimore pyrolysis and waste-fired steam generator emissions. *Waste Age*, 7(7):6-9, 77, July 1976.

Sutterfield, G. W. Refuse as a supplementary fuel for power plants; November 1973 through March 1974; interim progress report. Environmental Protection Publication SW-36d.iii. [Washington], U.S. Environmental Protection Agency, July 1974. 25 p.

Systems Technology Corporation. A technical, environmental and economic evaluation of the "wet processing system for the recovery and disposal of municipal solid waste." Environmental Protection Publication SW-109c. U.S. Environmental Protection Agency, 1975. [386 p.] (Distributed by National Technical Information Service, Springfield, Va., as PB-245 924.)

Appendix B

THE STATUS OF PRODUCT CHARGE STUDIES

INTRODUCTION

Section 205 of the Solid Waste Disposal Act, as amended by the Resource Recovery Act of 1970, directed EPA to investigate and study:

> . . . recommended incentives . . . and disincentives to accelerate the reclamation or recycling of materials from solid wastes . . . [and] the necessity and method of imposing disposal or other charges on packaging, containers, vehicles, and other manufactured goods, which charges would reflect the cost of final disposal, the value of recoverable components of the item, and any social costs associated with nonrecycling or uncontrolled disposal of such items.

One of the most widely recognized of the possible approaches to providing incentives for recycling is the "product charge" concept. Unlike local solid waste collection fees or service charges, which are levied on the solid waste generator at the point of collection or disposal, a product charge is a special sales or excise tax, most likely at the Federal level, levied at the point of product (or package) manufacture or point of wholesale or retail distribution. Product charges can serve two distinctly separate functions, either of which may receive greater or lesser emphasis in particular design proposals. The first is to provide an explicit financial incentive to producers and consumers to alter their jointly determined product and packaging decisions affecting solid waste quantities and characteristics. Second, the product charge, like all fees or taxes, serves as a source of public revenue. Depending on specific policy objectives, these revenues may or may not be earmarked for solid waste management or other special purposes.

Under the mandate of the Resource Recovery Act of 1970 EPA began to study the product charge concept along with other incentive and disincentive measures to curb waste, encourage resource recovery, and improve solid waste management practices. Many of these findings have been discussed in the three previous reports to Congress in this series.[1-3] More specifically, in the *Second Report to Congress* (March 1974, pp. 109-112), EPA presented findings from its initial analysis of the product charge concept. It was reported at that time that, from a conceptual and theoretical economic standpoint, the product charge approach has a number of desirable incentive and efficiency features. However, little quantitative work had been done on effectiveness and impact implications, and key questions were raised regarding administrative feasibility and equitability of impacts on different income groups.

This appendix provides preliminary results from work performed since the earlier report, specifically with respect to EPA contract studies on the effectiveness of product charges as a resource recovery and waste reduction incentive, on quantitative economic impacts, and on administrative cost. The intent here is not to present a comprehensive benefit-cost report or an analysis of options but to summarize the status of work in progress.

It should be noted that there are a number of other financial incentive proposals that could either complement or substitute for some elements of the product charge. One alternative is the recycling tax credit, which received initial approval in Congressional committees during the 94th Congress but which was subsequently defeated on the floor in both Houses. Another approach, the incremental waste disposal fee or user charge, is also under study by EPA. At the present time, pending further review and analysis, EPA does not recommend or endorse any particular incentive or disincentive mechanism at the national level to stimulate resource recovery. During the coming year, the alternatives will be further evaluated by the Resource Conservation Committee (see Chapter 1).

The following is divided into two parts. The first briefly reviews the theoretical rationale of a product charge as a waste management tool, describes various specific design options, and defines the typical base case design used in recent EPA impact studies. The second part presents preliminary findings from recent EPA contract studies on quantitative effectiveness and economic impacts of a typical product charge proposal.

CONCEPTS AND DESIGN OPTIONS

As the term has come to be used in the solid waste policy literature and in Congressional bills, a solid waste product charge is an excise tax on the material content of consumer products entering the solid waste stream. Though varying in specific design details, most product charge proposals to date have had three characteristics in common:

> A charge (Federal excise tax) on consumer products and packaging that is tied directly to projected solid waste management costs for the items in question.
>
> A special exemption or other incentive provision for the use of secondary materials in products and packaging.
>
> Provision for redistributing all or most of the revenue yield to local governments for solid waste management purposes.

In essence, these were the basic features of the "penny-a-pound" proposal, originally forwarded by Leonard S. Wegman at the 1970 Senate Hearings on the Resource Recovery Act.[4] That initiative provided the original conception for most later product charge designs, including those considered at one level or another by committees in both Houses of the 94th Congress during the winter and spring of 1975-76.[5-6]

Rationale

To a great extent, the rationale for the product charge concept rests on a basic principle in the economic theory of efficient resource allocation.[7] That is, for the market system to function efficiently in allocating all of the economy's scarce resources, every production and consumption activity should bear the full social cost of the good or service in question. Generally this means that prices of each product should include all costs of production. Economists have long argued that environmental damage costs should be included in this "total social cost" concept, along with the normally priced labor, capital, and other resources.[7]

It is also recognized by economists that costs of collecting and disposing of the discarded product when it enters the solid waste stream should, by the same reasoning, be charged against the specific product.[8]

At present, collection and disposal costs are typically paid for either indirectly and collectively through general real estate taxes or through fixed periodic levies on each discarder, often unrelated to the cost of providing the service. Thus, individual waste discarders are seldom charged in proportion to their total waste contribution; individual products are never charged as such. This failure to price solid waste services–that is, to charge each waste generator and each product the amount required to collect and process the relevant solid waste–is not only inequitable but also inefficient. The lack of proportional fees is inequitable in that the costs tend to be borne equally by taxpayers or in other ways unrelated to degree of responsibility. Inefficiency arises from the fact that when solid waste services are not appropriately priced, there is little incentive either to consumers or to producers to take action to minimize social costs.

Consumers are not provided with a market or economic incentive to consider the solid waste cost implications of their purchasing decisions. Since the perceived costs of products are lower than they actually are to the economy, consumers are encouraged to purchase more of the products. Under full-cost pricing, consumers might shift their purchasing more towards low-waste items (returnable containers, reusable tableware, longer-lived durable goods) and might give more emphasis to recycling as an alternative to disposal. Similarly, there is a lack of competitive incentive among producers to minimize the waste disposal costs associated with a product as there is to minimize costs of capital, labor, and other *directly priced* inputs to production. Waste-reducing actions by producers might include redesigning products to reduce material requirements or improve recyclability, or greater use of secondary material.

This failure of consumer product and packaging markets to fully reflect solid waste management costs amounts to an implicit subsidy for physically and economically wasteful production and consumption habits. It thus contributes to excessive use of material and energy resources and elevated levels of waste discharges, as described in Chapter 1.

A charge on products at their point of manufacture or sale, equal in amount to the product's prospective waste collection and disposal costs, would be a way of pricing solid waste collection and disposal services on a product-by-product basis. This would insure that those whose production and consumption decisions jointly and ultimately determine the quantity of solid waste will directly bear the costs resulting from their choices. In the jargon of economics, this would "internalize" the cost of solid waste management within the relevant market sectors. The primary social benefit would be to establish a framework of economic incentives to stimulate economically efficient waste reduction and recycling efforts by both producers and consumers.

As viewed by economists, the product charge is a possible tool for improving the overall economic efficiency of consumer goods markets in relation to raw materials supply and solid waste management sectors. Environmentalists may view the product charge approach primarily as an incentive system for encouraging resource recovery and waste reduction. City managers or others concerned with local solid waste management problems, on the other hand, may have little regard for the economic incentive features of the charge and may be much more concerned with possible revenue-sharing provisions.

As discussed below, the issue of what to do with the revenue yielded by a product charge is in principle completely separable from the concept of the charge as a market incentive mechanism. Whether revenues should be shared with local governments, as in most recent proposals, or designated for other purposes, or returned to individual families via income tax rebates is a matter for policy debate.

Practical Design Issues

Although the principal rationale and general outlines of a product charge system may be clear, a number of practical design considerations arise in any effort to translate the concept into a formal proposal. Design issues that have appeared most important according to EPA analyses thus far include the following:

What products should be included?
What material characteristic(s) (e.g., weight, volume) should be the basis for the charge?
At what point in the production-distribution system should products be charged?
How much should the charge be?
Should recycling be credited to the product in assessing the charge, and, if so, how?
Should there be a phasing in of the charge over time?
How should the revenues be utilized?

A "base case" product charge design, incorporating selected answers to the above questions, has been formulated in order to provide specific parameters for conducting preliminary impact and cost analyses. The following briefly describes the options and the specific design parameters selected for study purposes.

What products should be included? If one accepts the economists' rationale for the charge, then in principle all products entering municipal waste should be charged since all give rise to collection and disposal costs. In practice, the administrative complexity and expense of charging certain small-volume products or small-scale producers may be taken as sufficient reason to justify exemptions. It is not clear from EPA's analysis thus far at what point the added costs of including more products would exceed the additional benefits.

A more practical consideration from a research and analysis standpoint is that the complexity of the estimating tasks expands rapidly with expansion of the number of products considered. Thus, if for no other reason than to keep the research and estimating tasks within manageable bounds, the base case has thus far included only paper products and nonpaper packaging materials. Together these broad categories include about 80 percent of total nonfood product materials in the municipal waste stream, and the great majority of the short-lived or nondurable goods (Tables B1 and B2).

What material characteristic should be the basis for the charge? If the charge is intended to cause prices of individual products to reflect their prospective waste management costs, then some method must be selected for relating these costs to specific products. There are no entirely satisfactory or widely accepted methods, and relatively little is known in detail regarding the relationships between various product characteristics and real impacts on collection

TABLE B1

PAPER PRODUCT CATEGORIES INCLUDED IN PRODUCT CHARGE STUDY

- Paper
  - Newsprint
  - Printing, writing, and related paper
  - Packaging and industrial converting paper
  - Tissue and sanitary paper
- Containerboard*
  - Linerboard
  - Corrugating media
  - Container chip and filler
- Boxboard*
  - Folding boxboard
  - Setup boxboard
  - Milk cartons and food service containers

*Does not include miscellaneous paperboards.

TABLE B2

PACKAGING CATEGORIES INCLUDED IN PRODUCT CHARGE STUDY

Packaging material	SIC* code
Coverting paper	(26412, 26415)
Bag paper	(2431)
Glassine	(2643)
Boxboard	(2651, 2652, 2654, 2655)
Paper closures	(26451/81)
Cellophane	(2821)
Polyethylene	(2821)
Polypropylene	(2821)
Plastic sheet	(2821)
Polystyrene and other thermoformed	(2821)
Plastic closures	(30794/71)
Plastic bottles	(3079)
Plastic tubes, cups, jars, boxes, baskets, foams	(3079)
Glass jars	(3221)
Glass refillable bottles	(3221)
Glass nonrefillable bottles	(3221)
Steel cans	(3411)
Aerosol cans	(3411)
Metal closures	(34616, 24617)
Aluminum foil	(3352)
Aluminum plates	(3352)
Aluminum cans	(3411)
Collapsible tubes	(3496)

*Standard Industrial Classification.

and disposal costs. Furthermore, in practice, municipal wastes are usually collected as a mixed aggregate, which implies that costs may have to be allocated somewhat arbitrarily. Factors suggested as possibilities for allocating solid waste costs to specific products have included weight, volume, compacted volume, weight of incinerated residue, and "ease" of recycling or disposal. Weight is the most widely estimated factor and probably the most easily administered charge criterion and would seem appropriate for many, if not most, products. The benefits that might result from more precisely tailored charges must ultimately be judged against their greater administrative complexity; clearly more research on this subject is warranted.

There are at least two categories where an exception to the weight-based charge may be justified. Product categories (such as rigid packaging) where competing products have very different weight-to-volume ratios (aluminum versus glass containers, for example) but where the products nonetheless require roughly the same volume in mixed waste collection and disposal, might be more appropriately charged on a per item or volume basis. Bulky items, such as tires or refrigerators, which involve special collection and disposal problems, might also best be charged per item. For such large items, a direct estimate of their collection and disposal costs might be feasible.

The base case design presently relies primarily on a weight-based charge criterion for all items except rigid consumer packaging, where an attempt has been made to assign unit collection and disposal costs based on an estimated volume-cost criterion.

At what point in production should the charge be assessed? The principal issues here appear to be those of administrative feasibility and cost. In general, the closer to wholesale and retail levels of distribution, the more difficult and costly the charge program would become to administer. This is due to two factors, the first and perhaps more significant is the very large numbers of charge collection points; the second is possibly greater monitoring difficulties in certifying the primary and secondary material content of goods the further they are from their original production sources.

Usually, the further back in the production sequence towards bulk raw material production, the fewer the manufacturing sources and hence the fewer the collection and monitoring points. The principal problem at this early stage of material processing (say, the bulk paper manufacturing level) may be for the producer to distinguish the fraction of his total product output destined to enter the municipal waste stream. Another difficulty here may be in making allowances in the charge level for "prompt" or manufacturing scrap generated at subsequent production stages, since the charge concept would apply only to the weight (or volume) of the finished goods rather than on original bulk material weight (or volume).

Thus it appears that the precise points of charge application should be a matter for further administrative study and judgment. EPA impact analyses have assumed that charges will be at either the bulk processing stage (a papermill, for example) or at an intermediate production stage (for example, a can manufacturing plant), depending on the products in question.

How much should the charge be? In principle, if the economic efficiency rationale is to govern, the charges should reflect the total costs to society of collecting and disposing of the product. According to current EPA estimates, the direct costs of collecting, processing, and landfilling municipal wastes will average about $30 per ton, or 1.5 cents per pound, in 1976. This figure could be refined and improved by more extensive cost-sampling data. Some economists would also argue that, from a national efficiency viewpoint, land and capital costs are understated by conventional local government accounting and financing practices (see Chapter 1) and that a national level charge should reflect the true, higher social opportunity costs of land and capital.

EPA's recent impact study evaluations have been based on an assumed charge of $26 per ton for most product wastes and 0.5 cent per unit for rigid containers, based on estimates of nationwide average direct costs for 1974.

How should credits for recycling be handled? Most product charge proposals to date have specified that only the virgin material content of bulk raw materials or products would be charged. This, in effect, provides an implicit subsidy for the use of secondary (recycled) materials. It is further generally assumed, either implicitly or explicitly, that this credit for the use of recycled material should apply only to the post-consumer waste content, and not to either home scrap (recycled within the establishment) or other "prompt" or "new" industrial scrap sources.

It must be recognized that the task of assessing the recycled material content of bulk or finished raw materials and also determining the type of waste source may pose some administrative and monitoring difficulties.

An alternative concept would be to credit products according to estimates of that product's own material recycling (or energy recovery) record (rather than its secondary material content). This has certain merits but would also pose administrative difficulties in that it requires detailed recycling estimates, nationwide, for all major individual products and packaging types.

Thus far, EPA analysis has followed the original Wegman proposal in assuming a charge credit for the recycled material content of products.

Should the charge be phased in over time? Phasing in the charge by incremental amounts over, say, 5 or 10 years would have the salutary effect of avoiding shock impacts on affected industries and allow time for adjustments (recycling and waste reduction) that would mitigate the financial impacts on both producers and consumers. The EPA analysis has assumed a 10-year phase-in period (10 percent of the total charge being implemented each year), following the proposal in recent Congressional committee discussions.

How should the revenues be utilized? Under any charge scheme, Federal revenues will be generated. Several alternative uses of these revenues are possible, including: (1) allocating the revenues to the general fund as is done with many current excise taxes; (2) allocating part or all of the yield to Federal program areas; (3) rebating the revenues to individual households, possibly with writeoffs on income tax returns; and (4) distributing the revenues to local governments, either earmarked for solid waste management or other programs or as non-tied revenue sharing.

Most recent proposals have favored revenue sharing with local governments tied to some (generally undefined) solid waste management or resource recovery function. This area requires considerable additional analysis of options and their implications. EPA studies have not dealt with the revenue-sharing implications in detail. However, it can be noted that the estimated amount involved could total on the order of $2 billion per year if a $26-per-ton charge were fully implemented by 1980 or 1985.

Summary of Base-Case Product Charge Design

For purposes of quantitative estimation, EPA studies have utilized the following set of assumptions as a base-case design proposal:

> All paper products and most nonpaper packaging products of the types that enter the municipal solid waste stream would be subject to the charge (80 percent of the product waste stream).
>
> The charge is *weight-based* and is set at $26 per ton (1974 estimated U.S. average cost of municipal collection and disposal). Adjustment is made to a per unit container cost of $5.00 per thousand (0.5 cent each) for rigid containers.
>
> Products are charged as close to the bulk material processing point as feasible.
>
> Recycled material content (post-consumer waste only) of products is credited—i.e., the charge is based only on the virgin material content of products.
>
> The charge is phased in over a 10-year period.
>
> Revenues may or may not be shared with local governments.

PRELIMINARY IMPACT ESTIMATES

Based on the above assumptions and design considerations, EPA has conducted a series of studies to develop estimates of the approximate quantitative impacts of a product charge measure. Preliminary results for the following topics are described below: administrative costs; effects on recycling levels and waste reduction; prices of consumer goods; and the impact on household budgets.

It should be well noted that this work is still in progress; in particular, the specific numerical values will almost certainly change as the studies are reviewed and revised. Results could also change significantly if various design assumptions were altered.

Administrative Costs

EPA carried out a comparative evaluation of the workings of several existing excise tax programs to better understand the problems involved in implementing and administering the selected waste charge scheme.[9] Three Federal excise tax programs were considered: taxes for highway maintenance (gasoline and oil), the fish and wildlife conservation tax program (sporting goods equipment), and the dedicated airport maintenance tax program (airplane fuel, lubricants, equipment).

The study found that the administrative requirements for a product charge program are comparable with those for these existing programs. This finding reduces the concern that, despite its theoretical value, a national solid waste product charge scheme would prove excessively complicated or extremely costly to administer. In part, this finding reflects the simplified nature of the design under which the charge is restricted to a selected range of product categories and is collected at the manufacturing stage. These features significantly reduce the number of establishments that must be monitored (Table B3).

Some of the conclusions from this study are quoted below:

> Viewed in terms of tax collection tasks by the IRS, the proposed imposition of manufacturers' excise taxes or their equivalent on rigid consumer containers, flexible consumer packaging, and paper is quite feasible. As indicated by the previous analysis of specific precedents in the dedicated area, the IRS now administers manufacturers and retailers excise taxes which are at least as complex as the type of plan embodied in the Congressional draft initiatives.
>
> . . . .
>
> Assuming even that a separate excise tax return were filed for each establishment [Table B3], the total number of returns involved (9,240) would amount to about 0.7 percent of the 1,343,220 total of Federal excise tax returns filed in 1974. If each and every one of the presumptive 9,240 returns were examined, they would amount to only 10.5 percent of the 88,348 Federal excise returns examined in 1974.
>
> . . . .

TABLE B3

NUMBER OF ESTABLISHMENTS IN THE KEY INDUSTRIAL CLASSIFICATIONS COVERED BY THE PRODUCT CHARGE PROPOSAL*

SIC code	Industry	Number of establishments
2621	Papermills (except building paper)	349
2631	Paperboard mills	273
3221	Glass containers	117
3079	Misc. plastic products	7,678
2821	Plastic materials and resins	323
3353	Aluminum sheet, plate, and foil	51
3411	Metal cans	396
3466	Crowns and closures	53
	Total	9,240

*Compiled from memoranda prepared for the Resource Recovery Division, Office of Solid Waste, by Franklin Associates, Ltd.

> Collection costs for IRS (or other product charge collection authorities) under the plan would be moderate–certainly not in excess of 1 percent of gross yield and probably in the vicinity of 1/2 of 1 percent.

The overall administrative impact of the program would appear to be of an acceptable level based on this initial assessment; however, we anticipate continuing work in this area in conjunction with the Department of the Treasury under the Resource Conservation Committee mandate.

Effection Recycling and Waste Reduction

Under a product charge, materials would cost more because their waste management costs would be assessed against them; therefore, depending on particular situations, somewhat less material would be used. Moreover, under the base case charge proposal, the relative cost to the producers of using recycled materials would be reduced and thus recycling should increase.

EPA has sponsored two studies to estimate the quantitative impact of product charges on material use and recycling. The first was an earlier contract study (1973-74), focusing on containers and packaging materials, that examined a variation of the product charge along with a number of other incentive policy approaches.[10,11] The second, more recent, study was designed specifically to evaluate the base case charge proposal as applied to a broad range of paper products, including both packaging and nonpackaging product groups.[12] Since some paper products were included in both studies the results overlap somewhat. Moreover, since the studies were done at different times and employed rather different methods and policy assumptions, the results are not directly comparable. Despite certain major differences in approach, the two studies have nevertheless provided broadly similar conclusions indicating that a product charge set at a level approximating average waste collection and disposal costs would have significant impacts on the post-consumer solid waste stream (Tables B4 and B5). Work is now underway to provide an improved and more complete set of estimating methods in this field.

The estimated waste reduction impacts–that is, the price-induced reductions in demand–are relatively small in both studies, on the order of 2 to 3 percent of net waste. However, it should be noted that the study designs were only capable of estimating waste reduction effects due to shifts in consumer purchases.

TABLE B4

REDUCTIONS IN POST-CONSUMER SOLID WASTE RESULTING FROM A PRODUCT CHARGE ON PACKAGING MATERIALS, 1970 BASE YEAR*

(In thousands of tons per year)

Packaging material	Waste reduction effect[†]	Resource recovery effect[‡]	Total
Paper and board	232	1,078	1,310
Plastics	40	0	40
Glass	216	4,078	4,294
Steel	238	2,532	2,770
Aluminum	8	244	252
Total	734	7,941	8,666

*Miedema, Allen K., et al. (Research Triangle Institute). Preliminary Analysis of a Product Charge on Major Components of Post-Consumer Waste. EPA Contract No. 68-01-2981, June 7, 1976.

[†] The estimated reduction in material waste generation resulting from reduction of consumer purchases due to increased product prices.

[‡] The reduction in solid waste disposal attributable to increased material recycling.

TABLE B5

REDUCTIONS IN SOLID WASTES RESULTING FROM A PRODUCT CHARGE ON PAPER PRODUCTS, 1975 BASE YEAR*

(In thousands of tons per year)

Paper category	Waste reduction effect†	Resource recovery effect‡	Total
Paper	346	2,400	2,746
Container-board	122	6,493	6,615
Boxboard	1,274	1,189	2,463
Total	1,742	10,082	11,824

*Miedema, Allen K., et al. (Research Triangle Institute). Preliminary Analysis of a Product Charge on Major Components of Post-Consumer Waste. EPA Contract No. 68-01-2981, June 7, 1976.

†The estimated reduction in material waste generation resulting from reduction of consumer purchases due to increased product prices.

‡The reduction in solid waste disposal attributable to increased material recycling.

They were not able to simulate a complete range of effects of material cost changes on product designs or packaging material shifts at the producers' level.

The estimated increases in recycling levels for glass, steel, and aluminum packaging materials and for paper products in general are quite significant. In the packaging materials study, the estimated recycling effect amounted to a several-fold increase for glass, steel, and aluminum packaging, with an overall impact amounting to about 8 million tons (Table B4). This would have more than doubled the total material recycled in 1970 (the base year for calculating the estimates), and would have amounted to more than 10 percent of the total nonfood product and packaging component of the national waste stream.

The paper industry study, using the base-case charge design, an improved data base,[13] and more sophisticated methods, estimated a recycling increase for paper products alone of about 10 million tons for 1975. This compares with an actual 1974-76 recycling rate of about 8.5 million tons per year. The increased rate with a product charge is similar to the rate that was considered technically feasible but highly unlikely (without government action) in the industry-sponsored study, *Paper Recycling: The Art of the Possible.*[14]

Excessive attention should not be placed on particular numerical results in either of these tables due to the preliminary nature of the studies. Nevertheless, both studies generally support the conclusion that a product charge of the magnitude employed in the studies would have a significant impact on the waste stream and on material and energy conservation.

Consumer Price and Income Impacts

The increases in the price of those consumer products most likely to be affected by a charge measure have also been estimated (Tables B6 and B7). The estimated price increases are uniformly small—seldom greater than 1 or 2 percent of product prices and typically less than one-half of 1 percent. This is not surprising, since total solid waste management costs are less than 1 percent of total consumer expenditures. The price impacts shown here are based on an extreme assumption that the total effect of the charge is passed on to the consumer.

In addition to price, data was also developed on how a product charge would impact on poorer and richer families (Table B8). This distributional impact analysis was based on the Bureau of Labor Statistics consumer expenditure survey. As a percent of annual income, the charge would weigh more heavily on lower income groups and would thus be termed "regressive." However, the absolute level of the annual charge would not be large, the amounts ranging from about $8 per year for the poorest (lowest decile) families to $59 per year for the richest (highest decile) families. The median-income family would pay out a maximum of about $30 per year under the base case proposal.

The distribution of the revenues collected would, of course, affect the total net impact on consumers. For example, returning the funds to individual families via a Federal income tax rebate or writeoff would essentially neutralize the consumer budget impact. Returning funds to cities in some form of revenue-sharing approach also should, depending on how the funds were used, reduce the net impact on family incomes. The redistributional effects of some revenue-sharing approaches could compensate or offset, either partially or completely, any regressive features that a product charge might introduce into the overall tax and expenditure structure.

TABLE B6

INCREASE IN CONSUMER PRODUCT PRICES RESULTING FROM A PRODUCT CHARGE ON PACKAGING,* 1970 BASE YEAR

Consumer product	Price increase (percent)
Baked goods	0.2
Dairy products	0.2
Frozen foods	0.2
Fresh and cured meat	0.2
Fresh and cured fish and seafood	0.1
Fresh and cured poultry	0.1
Produce	0.2
Distilled spirits	0.2
Wine	0.3
Beer	2.2
Soft drinks	4.1
Prepared beverages	1.1
Candy and chewing gum	0.2
Canned foods	4.2
Cereals, flour, and macaroni	0.1
Pet foods	2.6
Tobacco products	0.1
Other foods	0.7
Soaps and detergents	1.1
Other cleaning supplies	0.3
Pesticides	0.0
Other household supplies	0.3
Packaged medications	0.3
Oral hygiene products	0.6
Cosmetics and hand products	0.5
Hair products	0.4
Shaving products	0.4
Other beauty aids	1.3
Other health aids	0.5
Other general merchandise	0.1
Weighted average†	0.3

*Miedema, Allen K., et al. (Research Triangle Institute). Preliminary Analysis of a Product Charge on Major Components of Post-Consumer Waste. EPA Contract No. 68-01-2981, June 7, 1976.

†The weighting is based on the amount consumers spent in each consumer product category.

TABLE B7

INCREASE IN CONSUMER PRODUCT PRICES RESULTING FROM A PRODUCT CHARGE ON PAPER PRODUCTS*

Rank†	Consumer product	Price increase (percent)
Paper		
1	Newspapers	1.39
2	Paper napkins, facial tissue	1.66
3	Periodicals	0.62
4	Book publishing	0.39
5	Shave lotions, cream, oils	0.15
6	Lubricants, oil, gasoline	0.04
7	Bread, cake, related products	0.08
8	Women's, children's apparel	0.04
9	Cigarettes	0.07
10	Fresh and frozen meats	0.04
Containerboard		
1	Fresh and frozen meats	0.02
2	Bottled and canned soft drinks	0.07
3	New passenger cars	0.02
4	Frozen fruits and vegetables	0.09
5	Canned and bottled beer	0.04
6	Games and toys	0.15
7	Pork sausages and like products	0.04
8	Women's, children's apparel	0.02
9	Package milk, cottage cheese	0.02
10	Bread, cake, related products	0.02
Boxboard		
1	Package milk, cottage cheese	0.12
2	Fresh and frozen meats	0.04
3	Pork sausages and like products	0.08
4	Bread, cake, related products	0.05
5	Frozen fruits and vegetables	0.10
6	Ice cream, frozen desserts	0.15
7	Soaps, detergents	0.14
8	Canned and bottled beer	0.04
9	Women's, children's apparel	0.02
10	Shave lotion, cream, oils	0.05

*Miedema, Allen K., et al. (Research Triangle Institute). Preliminary Analysis of a Product Charge on Major Components of Post-Consumer Waste. EPA Contract No. 68-01-2981, June 7, 1976.

†This ranking is based on the quantity of material consumed. The 10 consumer products that use the largest quantity of paper, containerboard, and boxboard are shown.

Estimated Product Charge Payments by Industries

To obtain an initial estimate of the charge payments that each affected industry would pay out under a waste charge measure, two extreme scenarios were analyzed (Table B9). In the "no recycle" case, the charge was assumed to have no recycling impact; in the second "high recycle" case, a relatively rapid increase in the rate of recycling was assumed. Since

TABLE B8

ANNUAL IMPACT ON FAMILY INCOMES OF PRODUCT CHARGE COMPARED WITH STATE AND LOCAL TAXES*

Family income before taxes	Decile†	Under $1,875	$1,875-3,399	$3,400-5,000	$5,001-6,899	$6,900-8,749	$8,750-10,499	$10,500-12,549	$12,500-15,199	$15,200-19,474	$19,475 & over
	Decile Average†	930	2,614	4,218	5,922	7,742	9,597	11,485	13,860	17,146	28,507
Family State & local taxes	Average	53.57	105.21	134.43	169.01	205.32	238.58	274.58	307.00	343.61	468.66
Annual increase in product costs per family	Packaging only	5.10	8.44	10.56	13.13	15.58	17.53	20.01	21.65	24.44	31.15
	Paper only	5.26	9.17	13.15	16.96	20.51	23.96	27.79	30.13	34.25	43.63
	Combined effect‡	7.87	13.39	18.43	23.53	28.30	32.73	37.80	40.96	46.47	59.21

*Miedema, Allen K., et al. (Research Triangle Institute). Preliminary Analysis of a Product Charge on Major Components of Post-Consumer Waste. EPA Contract No. 68-01-2981, June 7, 1976.

†*News*, U.S. Department of Labor, Bureau of Labor Statistics, May 15, 1975, Table 1. Based on number of facilities reporting, 88.3 percent of universe.

‡These estimates assume that the annual share of increased product costs per family due to paper packaging is proportional to the share of paper in packaging (50 percent).

TABLE B9

INDUSTRIAL CHARGE PAYMENTS FOR TWO RECYCLING SCENARIOS*

(In millions of dollars)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Glass:											
No recycle	20.9	42.3	64.3	85.4	107	126	148	169	189	208	207
High recycle	20.9	41.6	61.8	80.7	99.0	116	132	147	162	175	171
Steel:											
No recycle	33.2	66.7	100	134	167	200	232	262	291	318	310
High recycle	33.2	64.3	93.2	120	144	166	185	202	216	227	214
Aluminum cans and ends:											
No recycle	9.15	19.2	30.3	38.7	48.2	52.0	55.8	56.7	64.7	72.6	73.1
High recycle	8.80	17.8	27.3	33.4	40.6	42.3	44.8	44.9	50.0	54.8	53.8
Blow-molded plastic containers:											
No recycle	5.64	12.3	19.0	28.2	37.3	47.3	58.3	70.5	83.9	98.6	104
High recycle	5.64	13.3	19.7	27.9	36.6	45.9	56.0	67.0	78.7	93.7	98.8
Plastic packaging except blow-molded bottles:											
No recycle	7.90	17.0	27.3	38.6	51.2	55.1	80.6	97.6	115	133	139
High recycle	7.90	17.9	27.0	38.2	50.2	63.1	77.4	92.7	109	126	132
Paper and paperboard:											
No recycle	126	262	402	554	718	878	1050	1240	1450	1660	1700
High recycle	126	260	402	547	700	844	990	1120	1260	1400	1440
Total:											
No recycle	203	419	644	879	1130	1370	1620	1900	2190	2490	2530
High recycle	203	413	631	847	1070	1280	1480	1670	1880	2080	2110

*Compiled from memoranda prepared for the Resource Recovery Division, Environmental Protection Agency, by Franklin Associates, Ltd.

the charge is assumed to be levied only on virgin raw material in the base case design, the impact of a product charge on a given industry will be reduced to the extent that the industry converts to the use of secondary raw materials.

The total annual cash flow would be in the $2 billion range by the late 1980's. This is equal to somewhat less than half of all solid waste management costs by that time.

As noted earlier, the costs of administering the waste charge proposal are likely to be small; therefore, most of these funds would be available for redistribution. Under the revenue-sharing alternative for using the funds, for example, if net charge revenues did reach $2 billion by 1988 and the population at that time were 245 million (U.S. Bureau of the Census, Series E Projection, 1972 base year), a city of 100,000 would receive for environmental or other programs slightly over $800,000 in that year.

REFERENCES

1. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; first report to Congress. 3d ed. Environmental Protection Publication SW-118. Washington, U.S. Government Printing Office, 1974. 61 p.
2. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.
3. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and waste reduction; third report to Congress. chap. 2. Environmental Protection Publication SW-161. Washington, U.S. Government Printing Office, 1975. p. 16-32.
4. Wegman, L. S. Statement of Leonard S. Wegman, Leonard S. Wegman Co., Inc., New York. *In* U.S. Congress. Senate. Committee on Public Works. Resource Recovery Act of 1969 (pt. 3). Hearings before the Subcommittee on Air and Water Pollution, 91st Cong., 2d sess., on S. 2005, Feb. 20, 23-25, 1970. Washington, U.S. Government Printing Office, 1970. p. 1854-1866.
5. U.S. Congress. House. Committee on Commerce. Solid Waste Utilization Act, Dec. 1975. (Draft.)
6. U.S. Congress. Senate. Committee on Public Works, Subcommittee on Environmental Pollution. Hearings on effects of product disposal charges in municipal waste recovery and reuse, May 20, 1976.
7. Kneese, A. V. The economics of regional water quality management. Washington and Baltimore, Resources for the Future, Inc., and The Johns Hopkins Press, 1964. 215 p.
8. Baumol, W. J. Statement of Dr. W. J. Baumol, Professor of Economics, Princeton University. *In* U.S. Congress. Senate. Committee on Public Works. To Consider the Effects of Product Disposal Charges on Municipal Waste Recovery and Reuse. Hearing before the Panel on Materials Policy of the Subcommittee on Environmental Pollution, 94th Cong., 2d sess., May 20, 1976. Washington, U.S. Government Printing Office, 1976. p. 27-36.
9. Slitor, R. E. Administrative aspects of a dedicated manufacturers excise tax on solid waste creating products; final report. Washington, U.S. Environmental Protection Agency, Office of Solid Waste. (In preparation.)
10. Bingham, T. H., et al. [Research Triangle Institute]. An evaluation of the effectiveness and costs of regulatory and fiscal policy instruments on product packaging. Environmental Protection Publication SW-74c. U.S. Environmental Protection Agency, 1974. 301 p.
11. Miedema, A. K., T. H. Bingham, and J. Daber. Preliminary analysis of a product charge on major components of post-consumer solid wastes. Research Triangle Park, N. C., Research Triangle Institute, June 7, 1976. 36 p.
12. Miedema, A. K., et al. [Research Triangle Institute]. The case of virgin material charges: a theoretical and empirical evaluation in the paper industry; draft final report. Washington, U.S. Environmental Protection Agency. (In preparation.)
13. Arthur D. Little, Inc. Analysis of demand and supply for secondary fiber in the U.S. paper and paperboard industry. v. 1., sect. 1-8, 10. Environmental Protection Publication SW-115c.1. U.S. Environmental Protection Agency, 1976. 383 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-250 798.)
14. Franklin, W. E. Paper recycling—the art of the possible, 1970-1985. New York, American Paper Institute, 1973. 181 p.

Appendix C

BIBLIOGRAPHY OF EPA PUBLICATIONS ON RESOURCE RECOVERY AND WASTE REDUCTION

This Appendix provides a comprehensive list of EPA publications on the subjects of resource recovery and waste reduction and other closely-related subjects in the municipal solid waste field. The intent is to be comprehensive both historically and across EPA program areas. Thus, it includes publications as far back historically as records provide, at all levels of technical sophistication, and from all offices of EPA. This bibliography also includes papers by EPA personnel published in outside technical and trade journals, magazines, and symposia proceedings, as well as in-house and contract research reports. The list also includes a number of items originally published by other government agencies and private sources that have been reprinted by EPA. It includes selected, published Congressional or other hearings records which have been reprinted by EPA. It does not include unpublished speeches, nor does it include items on resource recovery from mining, industrial, or most other non-municipal waste sources.

The titles have been divided into 7 subject categories. References covering more than one topic have usually been placed in the "general" category (I) unless they had an obvious and predominant focus on one of the specifically listed categories. Titles falling outside the other specific subject areas were also classified in the "general" category. Of necessity, rather arbitrary decisions were made in many instances, and researchers in a particular subject are advised to also peruse other categories, particularly the general category.

Publications with an "AIM" number, except for items that are out of print (denoted by a "†"), may be ordered free of charge from: Solid Waste Information, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

References accompanied by a "PB" number are primarily contract and grant reports sponsored either by the Office of Solid Waste or the Office of Research and Development (or their predecessor offices). "PB" reports may be purchased from: National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161. (Microfiche copy price is $2.25; Xerox copy prices vary.)

Remaining items, including out-of-print titles, are usually available from EPA libraries, U.S. Government Printing Office depository libraries, public and university libraries, or occasionally by contacting the author directly.

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and products	106
Waste reduction	107
Materials recovery and recycling	113
Energy recovery from waste	115
Policy studies and papers	

I. GENERAL STUDIES, SURVEYS, OR REPORTS

Allison, G., S. Mooser, and P. Taylor. Más álla de la lata de basura. Spanish version of "Beyond the trashcan." Environmental Protection Publication SW-7tg. [Washington], U.S. Environmental Protection Agency, 1974. 23 p. (*AIM* no. 424)

Black, R. J. State activities in solid waste management, 1974. Environmental Protection Publication SW-158. [Washington], U.S. Environmental Protection Agency, June 1975. 216 p. (*AIM* no. 457)

Black, R. J. Summaries of solid waste management contracts; July 1, 1970–March 31, 1975. Environmental Protection Publication SW-5.4. [Washington], U.S. Environmental Protection Agency, Aug. 1975. 37 p. (*AIM* no. 469)

Black, R. J., and P. L. Davis. Refuse collection and disposal; an annotated bibliography, 1960–1961. rev. ed. Public Health Service Publication No. 91, Suppl. E. Washington, U.S. Government Printing Office, 1966. 69 p. (*AIM* no. 38)

Black, R. J., J. B. Wheeler, and W. G. Henderson. Refuse collection and disposal; an annotated bibliography, 1962–1963. Public Health Service Publication No. 91, Suppl. F. Washington, U.S. Government Printing Office, 1966. 134 p. (*AIM* no. 38)

Booz, Allen and Hamilton, Inc. Cost estimating handbook for transfer, shredding and sanitary landfilling of solid waste. Environmental Protection Publication SW-124c. U.S. Environmental Protection Agency, Aug. 1976. 82 p. (PB-256 444)

Breidenbach, A. W., *comp.* Summaries of solid waste intramural research and development projects. Environmental Protection Publication SW-14r. Washington, U.S. Government Printing Office, 1971. 24 p. (*AIM* no. 165)

†Clark, T. D. Economic realities of reclaiming natural resources in solid waste. *In* Institute of Environmental Sciences 1971 Annual Technical Meeting Proceedings, Los Angeles, Apr. 26-30, 1971. Mt. Prospect, Ill., Institute of Environmental Sciences. p. 39-43. Reprinted, [Washington], U.S. Environmental Protection Agency, 1971. 12 p. (*AIM* no. 225)

Committee guide; study of solid waste management. League of Women Voters Publication No. 699. Washington, League of Women Voters of the United States, Nov. 1971. 8 p. (*AIM* no. 259)

Connolly, J. A., and S. E. Radinsky, *comps.* Patent abstracts; United States solid waste management, 1945–1969. Public Health Service Publication No. 1793, Suppl. A. Washington, U.S. Government Printing Office, 1973. 452 p. (*AIM* no. 317)

Connolly, J. A., and S. E. Stainback. Solid waste management; abstracts from the literature–1964. Public Health Service Publication No. 91-1964, Suppl. G. Washington, U.S. Government Printing Office, 1971. 280 p. (*AIM* no. 231)

Connolly, J. A., and S. E. Stainback. Solid waste management; abstracts from the literature–1965. Public Health Service Publication No. 91-1965, Suppl. H. Washington, U.S. Government Printing Office, 1972. 216 p. (*AIM* no. 257)

Current views on solid waste management; recommended reading. Environmental Protection Publication SW-544. Washington, U.S. Environmental Protection Agency, [1976]. 10 p. (*AIM* no. 544)

†Darnay, A. Resource recovery and land protection; an environmental imperative. Presented at Spring Meeting, Paperboard Group, American Paper Institute, Greenbrier, W. Va., May 21, 1974. New York, American Paper Institute, 1974. 7 p. (*AIM* no. 413)

Drobny, N. L., H. E. Hull, and R. F. Testin. Recovery and utilization of municipal solid waste; a summary of available cost and performance characteristics of unit processes and systems. Public Health Service Publication No. 1908. Washington, U.S. Government Printing Office, 1971. 118 p. (*AIM* no. 177)

Franklin Institute Research Laboratories. Solid waste management; abstracts from the literature–1966. Public Health Service Publication No. 91-1966, Suppl. I. Washington, U.S. Government Printing Office, 1972. 197 p. (*AIM* no. 258)

Franklin Institute Research Laboratories. Solid waste management; abstracts from the literature–1967. Public Health Service Publication No. 91-1967, Suppl. J. Washington, U.S. Government Printing Office, 1972. 404 p. (*AIM* no. 281)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

†Franklin Institute Research Laboratories. Solid waste management; abstracts from the literature—1968. Public Health Service Publication No. 91-1968, Suppl. K. Washington, U. S. Government Printing Office, 1972. 286 p. (*AIM* no. 282)

Franklin, W. E., D. Bendersky, L. J. Shannon, and W. R. Park [Midwest Research Institute]. Resource recovery: catalogue of processes. U. S. Environmental Protection Agency, Feb. 1973. 141 p. (PB-214 148)

Garbe, Y. M., and S. J. Levy. Resource recovery plant implementation: guides for municipal officials—markets. Environmental Protection Publication SW-157.3. [Washington], U. S. Environmental Protection Agency, 1976. 47 p. (*AIM* no. 499)

†Golueke, C. G. Comprehensive studies of solid waste management; third annual report. Environmental Protection Publication SW-10rg. Washington, U. S. Government Printing Office, 1971. 201 p. (*AIM* no. 178)

Golueke, C. G. Solid waste management; abstracts and excerpts from the literature. v. 1-2. Public Health Service Publication No. 2038. Washington, U. S. Government Printing Office, 1970. 147 p. (*AIM* no. 127)

Golueke, C. G., and P. H. McGauhey. Comprehensive studies of solid waste management; first and second annual reports. Public Health Service Publication No. 2039. Washington, U. S. Government Printing Office, 1970. 245 p. (*AIM* no. 128)

Hale, S., Jr. The Federal resource recovery demonstration program. *Professional Engineer*, 48(6): 28-31, June 1973. (*AIM* no. 334)

‡Hale, S., Jr. Resource recovery losing ground. *Phoenix Quarterly*, 4(2):3-4, 1972. (*AIM* no. 289)

†Hart, S. A. Solid wastes management in Germany; report of the U. S. Solid Wastes Study Team visit, June 25-July 8, 1967. Public Health Service Publication No. 1812. Washington, U. S. Government Printing Office, 1968. 18 p. (*AIM* no. 59)

Hawkins, D. Resource recovery plant implementation: guides for municipal officials—further assistance. Environmental Protection Publication SW-157.8. [Washington], U. S. Environmental Protection Agency, 1975. 29 p. (*AIM* no. 470)

Hopper, R. E. A nationwide survey of resource recovery activities. Environmental Protection Publication SW-142. [Washington], U. S. Environmental Protection Agency, Jan. 1975. 74 p. (*AIM* no. 432)

Humber, N. Waste reduction and resource recovery—there's room for both. *Waste Age*, 6(11):38, 40-41, 44, Nov. 1975. (*AIM* no. 505)

International Research Group on Refuse Disposal (IRGRD); information bulletin numbers 21-31, August 1964 to December 1967. Rockville, Md., U. S. Department of Health, Education, and Welfare, 1969. 387 p. [Translated by the Israel Program for Scientific Translations.] (*AIM* no. 89)

International Research Group on Refuse Disposal (IRGRD); information bulletin number 32, April 1968. Rockville, Md., U. S. Department of Health, Education, and Welfare, 1969. 41 p. [Translated by the Israel Program for Scientific Translations.] (*AIM* no. 142)

International Research Group on Refuse Disposal (IRGRD); information bulletin number 33, August 1968. Rockville, Md., U. S. Department of Health, Education, and Welfare, 1969. 27 p. [Translated by the Israel Program for Scientific Translations.] (*AIM* no. 143)

International Research Group on Refuse Disposal (IRGRD); information bulletin number 35, May 1969. Rockville, Md., U. S. Department of Health, Education, and Welfare, 1969. 46 p. [Translated by the Israel Program for Scientific Translations.] (*AIM* no. 145)

Lefke, L. W., A. G. Keene, R. A. Chapman, and H. Johnson, *comps*. Summaries of solid waste research and training grants—1970. Public Health Service Publication No. 1596. Washington, U. S. Government Printing Office, 1971. 134 p. Addendum through July 31, 1971. 8 p. [Insert.] (*AIM* no. 190)

Levy, S. J., and H. G. Rigo. Resource recovery plant implementation: guides for municipal officials—technologies. Environmental Protection Publication SW-157.2. Washington, U. S. Environmental Protection Agency, 1976. 81 p. (*AIM* no. 500)

Lingle, S., *ed*. Resource recovery technology update from the U.S.E.P.A.; demonstrating resource recovery. *Waste Age*, 7(6):19, 22, 26, 42, 44-46, June 1976. (*AIM* no. 528)

Lonergan, R. P., and E. M. Herson. Solid waste—a natural resource? *In* Man and the quality of his environment; Western Resources Papers, 1967. J. E. Flack and M. C. Shipley, *eds*. [Boulder], University of Colorado Press, 1968. p. 107-120. (*AIM* no. 77)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

McEwen, L. B., Jr. A nationwide survey of resource recovery activities. Environmental Protection Publication SW-142.1. Washington, U.S. Environmental Protection Agency, 1976. (*AIM* no. 432)

Meyers, S. Status of solid waste management in the United States. Presented at 2d International Congress of the International Solid Wastes Association, Padua, June 24, 1976. Washington, U. S. Environmental Protection Agency. 22 p. (*AIM* no. 526)

†Midwest Research Institute. Resource recovery; the state of technology. [Prepared for the Council on Environmental Quality.] Washington, U. S. Government Printing Office, 1973. 67 p. (*AIM* no. 321)

Mitre Corporation. The resource recovery industry; a survey of the industry and its capacity. Environmental Protection Publication SW-501c. Washington, U. S. Government Printing Office, 1976. 92 p. (*AIM* no. 501)

Mitre Corporation. Resource recovery plant implementation: guides for municipal officials—procurement. Environmental Protection Publication SW-157.5. [Washington], U. S. Environmental Protection Agency, 1976. 66 p. (*AIM* no. 495)

‡Muhich, A. J. Grants encourage new waste disposal methods. *Journal of Environmental Health*, 32(5):572-578, Mar.-Apr. 1970. (*AIM* no. 121)

National Analysts, Inc. Metropolitan housewives' attitudes toward solid waste disposal. U. S. Environmental Protection Agency, 1972. 114 p. (PB-213 340)

Office of Solid Waste Management Programs, Resource Recovery Division. Current recommended readings on resource recovery and waste reduction. Environmental Protection Publication SW-536. [Washington], U. S. Environmental Protection Agency, 1976. 13 p. (*AIM* no. 536)

Ottinger, R. S., et al. [TRW Systems Group]. Recommended methods of reduction, neutralization, recovery or disposal of hazardous waste. U. S. Environmental Protection Agency, 1973. 16 v. (PB-224 579-Set)

‡Peterson, B. There's gold in your garbage. *Scouting*, 62(7):47-48, 84-86, Oct. 1974. Reprinted, [Washington], U.S. Environmental Protection Agency, 1974. 4 p. (*AIM* no. 421)

Randol, R. E. Resource recovery plant implementation: guides for municipal officials—financing. Environmental Protection Publication SW-157.4. [Washington], U.S. Environmental Protection Agency, 1975. 20 p. (*AIM* no. 471)

Randol, R. E. Resource recovery plant implementation: guides for municipal officials—risks and contracts. Environmental Protection Publication SW-157.7. [Washington], U.S. Environmental Protection Agency, 1976. 52 p. (*AIM* no. 496)

†Recycling. Falls Church, Va., Stuart Finley, Inc., [1971]. 6 p. [Flyer.] (*AIM* no. 210)

Resource Conservation and Recovery Act of 1976, Public Law 94-580, 94th Congress, S. 2150—Oct. 21, 1976. [Washington, U.S. Government Printing Office,] 1976. [47 p.] (*AIM* no. 171)

Resource recovery, recycling, and reuse. *In* Citizens' Advisory Committee on Environmental Quality. Annual report to the President and to the Council on Environmental Quality for the year ending May 1972. Washington, U.S. Government Printing Office, [1972]. p. 33-41. Reprinted, [Cincinnati], U.S. Environmental Protection Agency, 1972. [10 p.] (*AIM* no. 307)

Shilepsky, A. Resource recovery plant implementation: guides for municipal officials—interim report. Environmental Protection Publication SW-152. [Washington], U.S. Environmental Protection Agency, Oct. 1975. 38 p. (*AIM* no. 480)

Skinner, J. H. Resource recovery: the Federal perspective. *Waste Age*, 5(1):12-14, 54, Jan./Feb. 1974. Reprinted, [Washington], U.S. Environmental Protection Agency, 1974. 3 p. (*AIM* no. 350)

Smith, F. A. Resource recovery plant cost estimates: a comparative evaluation of four recent dry-shredding designs. Environmental Protection Publication SW-163. [Washington], U.S. Environmental Protection Agency, Oct. 1975. 20 p. (*AIM* no. 482)

The Solid Waste Disposal Act; Title II of Public Law 89-272, 89th Congress, S. 306-October 20, 1965, as amended by The Resource Recovery Act of 1970, Public Law 91-512-91st Congress, H. R. 11833-October 26, 1970; by Public Law 93-14-93rd Congress, H. R. 5446-April 9, 1973 (To extend the amended Solid Waste Disposal Act—For one year); and by Public Law 93-611-93rd Congress, H. R. 16045-January 2, 1975 (To amend the Solid Waste Disposal Act to authorize appropriations for fiscal year 1975). Environmental Protection Publication SW-1.3. [Washington], U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, 1975. 14 p. (*AIM* no. 171)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

‡Solid waste disposal and resource recovery grants. *Federal Register*, 36(181):18622-18628, Sept. 17, 1971. (*AIM* no. 221)

Solid waste; disposal, reuse present major problems. *Congressional Quarterly; Weekly Report*, 31(17): 1019-1023, Apr. 28, 1973. (*AIM* no. 330)

Solid waste management; an overview of State legislation. Washington, National League of Cities – United States Conference of Mayors, [1976]. 60 p.

Sponagle, C. E., and P. L. Stump. Solid waste management demonstration grant projects—1971; for grants awarded during the period June 1, 1966—June 30, 1971. Public Health Service Publication No. 1821. Washington, U.S. Government Printing Office, 1971. 247 p. (*AIM* no. 232)

Stump, P. L., *comp.* Solid Waste Demonstration Projects; Proceedings of a Symposium, Cincinnati, May 4-6, 1971. Washington, U.S. Government Printing Office, 1972. 256 p. (*AIM* no. 311)

Sussman, D. B. Resource recovery plant implementation: guides for municipal officials—accounting format. Environmental Protection Publication SW-157.6. [Washington], U.S. Environmental Protection Agency, 1976. 17 p. (*AIM* no. 493)

†Talty, J. T. Resource recovery—a new solid waste management philosophy and technology. Presented at the 10th Annual Environmental and Water Resources Engineering Conference, Vanderbilt University, Nashville, June 1971. [Cincinnati], U.S. Environmental Protection Agency. 9 p. Reprinted 1971. 11 p. (*AIM* no. 196)

Train, R. E. Solid waste management: horizons unlimited. Presented at International Waste Equipment and Technology Exposition, Chicago, June 2, 1976. Washington, U.S. Environmental Protection Agency. 16 p. (*AIM* no. 525)

U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Decision-makers guide in solid waste management. Environmental Protection Publication SW-500. Washington, U.S. Government Printing Office, 1976. 158 p. (*AIM* no. 390)

U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; first report to Congress. 3d ed. Environmental Protection Publication SW-118. Washington, U.S. Government Printing Office, 1974. 61 p. (*AIM* no. 352)

U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and source reduction; second report to Congress. Environmental Protection Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p. (*AIM* no. 353)

U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and waste reduction; third report to Congress. Environmental Protection Publication SW-161. Washington, U.S. Government Printing Office, 1975. 96 p. (*AIM* no. 448)

‡U.S. finds a rich resource: the nation's trash pile. *U.S. News & World Report*, 76(19):63-64, 66, May 13, 1974. (*AIM* no. 396)

Wahl, D., and R. L. Bancroft. Solid waste management today . . . bringing about municipal change. *Nation's Cities*, 13(8):17-32, Aug. 1975. (*AIM* no. 466)

Weaver, L., *ed.* Proceedings; the Surgeon General's Conference on Solid Waste Management for Metropolitan Washington, July 19-20, 1967. Public Health Service Publication No. 1729. Washington, U.S. Government Printing Office. 194 p. (*AIM* no. 30)

West Virginia University, Department of Chemical Engineering. Solid waste: a new natural resource. U.S. Environmental Protection Agency, May 1971. 18 p. (PB-211 256)

Wiley, J. S., *ed.* International Research Group on Refuse Disposal (IRGRD); information bulletin numbers 1-12, November 1956 to September 1961. Washington, U.S. Government Printing Office, 1969. 308 p. (*AIM* no. 21)

Wiley, J. S., *ed.* International Research Group on Refuse Disposal (IRGRD); information bulletin numbers 13-20, December 1961 to May 1964. Washington, U.S. Government Printing Office, 1969. 274 p. (*AIM* no. 22)

Williams, E. R. Refuse collection and disposal; an annotated bibliography, 1956-1957. Public Health Service Publication No. 91, Suppl. C. Washington, U.S. Government Printing Office, 1958. 48 p. (*AIM* no. 36)

Williams, E. R., and R. J. Black. Refuse collection and disposal; an annotated bibliography, 1958-1959. Public Health Service Publication No. 91, Suppl. D. Washington, U.S. Government Printing Office, 1961. 73 p. (*AIM* no. 37)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

Williams, T. F. Conservation and common sense. Presented at National Conference "Land Application of Waste Materials," Soil Conservation Society of America, Des Moines, Mar. 17, 1976. [Washington], U.S. Environmental Protection Agency. 21 p. (*AIM* no. 515)

II. SOLID WASTE QUANTITY AND COMPOSITION AND FORECASTS

Arthur D. Little, Inc. Analysis of demand and supply for secondary fiber in the U.S. paper and paperboard industry. v. 1, sec. I-VIII, X. U.S. Environmental Protection Agency, Oct. 1975. 383 p. (PB-250 798)

Arthur D. Little, Inc. Analysis of demand and supply for secondary fiber in the U.S. paper and paperboard industry. v. 2, sec. IX. Process economics. U.S. Environmental Protection Agency, Oct. 1975. 257 p. (PB-250 905)

Arthur D. Little, Inc. Analysis of demand and supply for secondary fiber in the U.S. paper and paperboard industry. v. 3. Appendices. U.S. Environmental Protection Agency, 1976. 422 p. (PB-250 802)

†Black, R. J., A. J. Muhich, A. J. Klee, H. L. Hickman, Jr., and R. D. Vaughan. The national solid wastes survey; an interim report. [Cincinnati], U.S. Department of Health, Education, and Welfare, [1968]. 53 p. (*AIM* no. 26)

Boyd, G. B., and M. B. Hawkins. Methods of predicting solid waste characteristics. Environmental Protection Publication SW-23c. Washington, U.S. Government Printing Office, 1971. 28 p. (*AIM* no. 235)

Darnay, A., and W. E. Franklin. The role of packaging in solid waste management, 1966 to 1976. Public Health Service Publication No. 1855. Washington, U.S. Government Printing Office, 1969, 205 p. (*AIM* no. 44)

‡DeGeare, T. V., Jr., and J. E. Ongerth. Empirical analysis of commercial solid waste generation. *Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers,* 97(SA6):843-850, Dec. 1971. (*AIM* no. 240)

Franklin, W. E., and A. Darnay. The role of nonpackaging paper in solid waste management, 1966 to 1976. Public Health Service Publication No. 2040. Washington, U.S. Government Printing Office, 1971. 76 p. (*AIM* no. 170)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

International Research and Technology Corporation. Forecasting the composition and weight of household solid wastes using input-output techniques; final report. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

International Research and Technology Corporation. Problems and opportunities in management of combustible solid wastes. U.S. Environmental Protection Agency, 1973. 517 p. (PB-222 467)

Kiefer, I. The role of packaging in solid waste management, 1966 to 1976. Washington, U.S. Government Printing Office, 1971. 28 p. (*AIM* no. 243)

†Lefke, L. W. Resource recovery in solid waste management. Environmental Protection Publication SW-67r. [Washington], U.S. Environmental Protection Agency, 1971. 14 p. (*AIM* no. 241)

Midwest Research Institute. Base line forecasts of resource recovery, 1972 to 1990: final report. Environmental Protection Publication SW-107c. U.S. Environmental Protection Agency, 1975. 386 p. (PB-245 924)

Muhich, A. J., A. J. Klee, and P. W. Britton. Preliminary data analysis; 1968 national survey of community solid waste practices. Public Health Service Publication No. 1867. Washington, U.S. Government Printing Office, 1968. 483 p. (*AIM* no. 28)

Smith, F. A. Comparative estimates of post-consumer solid waste. Environmental Protection Publication SW-148. [Washington], U.S. Environmental Protection Agency, May 1975. 18 p. (*AIM* no. 443)

Smith, F. A. Quantity and composition of post-consumer solid waste: material flow estimates for 1973 and baseline future projections. *Waste Age,* 7(4):2,6-8,10, Apr. 1976. (*AIM* no. 498)

Smith, F. L., Jr. A solid waste estimation procedure; material flows approach. Environmental Protection Publication SW-147. [Washington], U.S. Environmental Protection Agency, May 1975. 56 p. (*AIM* no. 445)

Stone, R., and D. E. Brown [Ralph Stone and Company, Inc.]. Forecasts of the effects of air and water pollution controls on solid waste generation. U.S. Environmental Protection Agency, 1974. 830 p. (PB-238 819)

University of Chicago. Socio-economic factors affecting demand for municipal collection of household refuse. U.S. Environmental Protection Agency, 1973. 58 p. (PB-225 020)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

U.S. Department of Transportation, Federal Highway Administration. 1974 Highway litter study; report to Congress. House Document No. 93-326 (93rd Congress, 2d Session). Washington, U.S. Government Printing Office, 1974. 77 p. (*AIM* no. 455)

III. ENVIRONMENTAL IMPACTS, RAW MATERIALS AND ENERGY REQUIREMENTS FOR MATERIALS AND PRODUCTS

Bingham, T. H., et al. [Research Triangle Institute]. An analysis of the materials and natural resource requirements and residuals generation of personal consumption expenditure items. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Claussen, E. L. Environmental impacts of packaging. [Washington], U.S. Environmental Protection Agency, 1973. 10 p. (*AIM* no. 332)

Gordian Associates, Inc. An energy analysis of the production of selected products in six basic material industries. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Gordian Associates, Inc. Environmental impacts associated with selected options for the recycling of materials, reuse of products and recovery of energy from solid waste. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Gordian Associates, Inc. Environmental impacts of production of virgin and secondary paper, glass and rubber products. Environmental Protection Publication SW-128c. U.S. Environmental Protection Agency, 1975. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Hunt, R. G., et al. [Midwest Research Institute]. Resource and environmental profile analysis of nine beverage container alternatives; final report. v. 1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p. (*AIM* no. 405; PB 253 486)

Lowe, R. A., M. Loube, and F. A. Smith. Energy conservation through improved solid waste management. Environmental Protection Publication SW-125. [Washington], U.S. Environmental Protection Agency, 1974. 39 p., app. (*AIM* no. 378)

Vaughan, D. A., et al. [Battelle Columbus Laboratories]. Environmental assessment of future disposal methods for plastics in municipal solid waste. U.S. Environmental Protection Agency, June 1975. 86 p. (PB-243 366)

Ziegler, R. C., et al. [Calspan Corporation]. Environmental impacts of virgin and recycled steel and aluminum. Environmental Protection Publication SW-117c. U.S. Environmental Protection Agency, 1976. 125 p. (PB-253 487)

IV. WASTE REDUCTION

Claussen, E. Oregon's bottle bill; the first six months. Environmental Protection Publication SW-109. Washington, U.S. Government Printing Office, 1973. 14 p. (*AIM* no. 325)

Claussen, E. Packaging source reduction; can industry and government cooperate? Environmental Protection Publication SW-136. [Washington], U.S. Environmental Protection Agency, 1974. 17 p. (*AIM* no. 422)

Darnay, A. Environmental protection, residuals management, and resources—the future is now. Presented at Annual Meeting of National Packaging Association, Boca Raton, Fla., Mar. 12-16, 1974. [Washington], U.S. Environmental Protection Agency, 1974. 23 p. (*AIM* no. 364)

Hickman, L., Jr. Packaging industry and government. *Waste Age*, 2(6):12-14, Nov.-Dec. 1971. (*AIM* no. 246)

Peterson, C. Price comparison survey of beer and soft drinks in refillable and non-refillable containers. Washington, U.S. Environmental Protection Agency, 1976. (In preparation.)

Proceedings; 1st National Conference on Packaging Wastes, Sept. 22-24, 1969. Environmental Protection Publication SW-9rg. Washington, U.S. Government Printing Office, 1971. 242 p. (*AIM* no. 172)

Sachsel, G. F., *comp*. Design of Consumer Containers for Re-use or Disposal; Proceedings of the Solid Waste Resources Conference, [Columbus], May 12-13, 1971. Washington, U.S. Government Printing Office, 1972. 330 p. (*AIM* no. 261)

Skinner, J. H. Reduce the incentive to waste. Paper No. 7d. Presented at 80th National Meeting, American Institute of Chemical Engineers, Boston, Sept. 8, 1975. 9 p. (*AIM* no. 500)

Skinner, J. H. Statement of John H. Skinner before the Wisconsin Senate Commerce Committee hearings on beverage container deposit legislation, Madison, May 7, 1976. [Washington, U.S. Environmental Protection Agency], 1976. 13 p.

Source reduction fact sheet; reducing waste at its source, program of International Paper Company and Wells Dairy. Washington, U.S. Environmental Protection Agency, May 1975. 2 p. (*AIM* no. 447)

Source reduction fact sheet; Red Owl Stores program. [Washington], U.S. Environmental Protection Agency, 1974. 3 p. (*AIM* no. 416)

Train, R. E. The uses and abuses of waste. *Compost Science,* 16(3):11-13, May-June 1975. (*AIM* no. 476)

Train, R. E. Win the war on waste. Presented at 3d National Congress on Waste Management Technology and Resource Recovery, San Francisco, Nov. 14, 1974. [Washington, U.S. Environmental Protection Agency, 1975.] 15 p. (*AIM* no. 460)

U.S. Environmental Protection Agency. Solid waste management; guidelines for beverage containers. *Federal Register,* 41(184):41202- 41205, Sept. 21, 1976. (*AIM* no. 463)

U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Proceedings; 1975 Conference on Waste Reduction, April 2-3, 1975, Washington, D.C. Environmental Protection Publication SW-7p. Washington, U.S. Government Printing Office, 1975. 152 p. (*AIM* no. 461)

†Vaughan, R. D. Solid waste management and the packaging industry. [Cincinnati], U.S. Department of Health, Education, and Welfare, 1969. 20 p. (*AIM* no. 107)

Wahl, D., and G. Allison. Reduce; targets, means and impacts of source reduction. League of Women Voters Publication No. 576. Washington, League of Women Voters of the United States, 1975. 47 p. (*AIM* no. 456)

V. MATERIALS RECOVERY AND RECYCLING

Albrecht, O. W., and R. G. McDermott. Economic and technological impediments to recycling obsolete ferrous solid waste. U.S. Environmental Protection Agency, 1973. 62 p. (PB-223 034)

‡Alexander, T. Where will we put all that garbage? *Fortune,* 76(5):149-151, 189-190, 192, 194, Oct. 1967. Reprinted, [Cincinnati], U.S. Department of Health, Education, and Welfare, [1970], 13 p. (*AIM* no. 120)

Alter, H., and W. R. Reeves [National Center for Resource Recovery, Inc.]. Specifications for materials recovered from municipal refuse. U.S. Environmental Protection Agency, National Environmental Research Center, May 1975. 120 p. (PB-242 540)

A. M. Kinney, Inc. Franklin, Ohio's solid waste disposal and fiber recovery demonstration plant; final report. Environmental Protection Publication SW-47d.2. U.S. Environmental Protection Agency, 1974. 2 v. (PB-234 715–PB-234 716)

Ananth, K. P., and J. Shum [Midwest Research Institute]. Fine shredding of municipal solid waste. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, July 1976. 71 p. (PB-257 105)

Arella, D. G. Recovering resources from solid waste using wet-processing; EPA's Franklin, Ohio, demonstration project. Environmental Protection Publication SW-47d. Washington, U.S. Government Printing Office, 1974. 26 p. (*AIM* no. 408)

Arella, D. G., and Y. M. Garbe. Mineral recovery from the noncombustible fraction of municipal solid waste; a proposed project to demonstrate incinerator residue recovery. Environmental Protection Publication SW-82d.1. [Washington], U.S. Environmental Protection Agency, Dec. 1975. 14 p. (*AIM* no. 491)

Banks, M. E., W. D. Lusk, and R. S. Ottinger. New chemical concepts for utilization of waste plastics. [Public Health Service Publication No. 2125.] Washington, U.S. Government Printing Office, 1971. 129 p. (*AIM* no. 222)

Barbour, J. F., R. R. Groner, and V. H. Freed. The chemical conversion of solid wastes to useful products. U.S. Environmental Protection Agency, 1974. 168 p. (PB-233 178)

Battelle Memorial Institute. A study to identify opportunities for increased solid waste utilization. v. 1. General report. Environmental Protection Publication SW-40d.1. U.S. Environmental Protection Agency, 1972. 178 p. (PB-212 792)

Battelle Memorial Institute. A study to identify opportunities for increased solid waste utilization. v. 2-7. Aluminum, copper, lead, zinc, nickel and stainless steel, and precious metal reports. Environmental Protection Publication SW-40d. U.S. Environmental Protection Agency, 1972. 608 p. (PB-212 730)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

Battelle Memorial Institute. A study to identify opportunities for increased solid waste utilization. v. 8-9. Paper and textile reports. Environmental Protection Publication SW-40d.3. U.S. Environmental Protection Agency, 1972. 342 p. (PB-212 731)

Boettcher, R. A. Air classification of solid wastes; performance of experimental units and potential applications for solid waste reclamation. Environmental Protection Publication SW-30c. Washington, U.S. Government Printing Office, 1972. 73 p. (*AIM* no. 256)

Booz Allen Applied Research, Inc. An analysis of the abandoned automobile problem. U.S. Environmental Protection Agency, 1973. 196 p. (PB-221 879)

Brand, B. G. Scrap rubber tire utilization in road dressings. U.S. Environmental Protection Agency, 1974. 51 p. (PB-232 559)

Breidenbach, A. W., et al. Composting of municipal solid wastes in the United States. Environmental Protection Publication SW-47r. Washington, U.S. Government Printing Office, 1971. 103 p. (*AIM* no. 212)

Callihan, C. D., and C. E. Dunlap. Single-cell proteins from cellulosic wastes. U.S. Environmental Protection Agency, 1973. 89 p. (PB-223 873)

Carlson, O. N., and F. A. Schmidt. The metallurgical upgrading of automotive scrap steel. U.S. Environmental Protection Agency, 1973. 90 p. (PB-223 740)

‡Carnes, R. A., and R. D. Lossin. An investigation of the pH characteristics of compost. *Compost Science,* 11(5):18-21, Sept.-Oct. 1970. Reprinted, [Cincinnati, U.S. Environmental Protection Agency, 1971.] 4 p. (*AIM* no. 158)

Carroll, T. E., et al. [Battelle Columbus Laboratories]. Review of landspreading of liquid municipal sewage sludge. U.S. Environmental Protection Agency, June 1975. 110 p. (PB-245 271)

Converse, A. O., H. E. Grethlein, S. Karandikar, and S. Kuhrtz. Acid hydrolysis of cellulose in refuse to sugar and its fermentation to alcohol. U.S. Environmental Protection Agency, 1973. 113 p. (PB-221 239)

Cukor, P., M. J. Keaton, and G. Wilcox [Teknekron, Inc., and the Institute of Public Administration]. A technical and economic study of waste oil recovery. pt. 1. Federal research on waste oil from automobiles. Environmental Protection Publication SW-90c.1. U.S. Environmental Protection Agency, 1974. 107 p. (PB-237 618)

Cukor, P., M. J. Keaton, and G. Wilcox [Teknekron, Inc., and the Institute of Public Administration]. A technical and economic study of waste oil recovery. pt. 2. An investigation of dispersed sources of used crankcase oils. Environmental Protection Publication SW-90c.2. U.S. Environmental Protection Agency, 1974. 63 p. (PB-237 619)

Cukor, P., M. J. Keaton, and G. Wilcox [Teknekron, Inc., and the Institute of Public Administration]. A technical and economic study of waste oil recovery. pt. 3. Economic, technical and institutional barriers to waste oil recovery. Environmental Protection Publication SW-90c.3. U.S. Environmental Protection Agency, 1974. 143 p. (PB-237 620)

Cukor, P., and T. Hall [Teknekron, Inc.]. A technical and economic study of waste oil recovery. pt. 4. Energy consumption in waste oil recovery. U.S. Environmental Protection Agency, 1976. (In press; to be distributed by National Technical Information Service, Springfield, Va.)

Daly, W. H., and L. P. Ruiz. Fabrication of single cell protein from cellulosic wastes. U.S. Environmental Protection Agency, 1975. 71 p. (PB-239 502)

Dane, S., *comp.* The national buyer's guide to recycled paper. Washington, Environmental Educators, Inc., 1973. 208 p. (*AIM* no. 343)

Darnay, A. Recycling; assessment and prospects for success. Environmental Protection Publication SW-81. Washington, U.S. Government Printing Office, 1972. 14 p. (*AIM* no. 286)

Darnay, A., and W. E. Franklin. Salvage markets for materials in solid wastes. Environmental Protection Publication SW-29c. Washington, U.S. Government Printing Office, 1972. 187 p. (*AIM* no. 293)

Dehn, W. T. Solving the abandoned car problem in small communities. Environmental Protection Publication SW-70ts.1. Washington, U.S. Government Printing Office, 1974. 23 p. (*AIM* no. 354)

Dindal, D. L. Ecology of compost; a public involvement project. Syracuse, State University of New York, College of Environmental Science and Forestry, 1972. 12 p. (*AIM* no. 322)

Experimental composting research and development; joint U.S. Public Health Service-Tennessee Valley Authority Composting Project, Johnson City, Tenn. Washington, U.S. Government Printing Office, 1968. 6 p. [Flyer.] (*AIM* no. 15)

Fookson, A., and G. Frohnsdorff. The nitrite-accelerated photochemical degradation of cellulose as a pretreatment for microbiological conversion to protein. U.S. Environmental Protection Agency, 1973. 102 p. (PB-222 115)

---

‡Available in public and university libraries.

Foran, J. F., et al. Raw materials transportation costs and their influence on the use of wastepaper and scrap iron and steel. U.S. Envrionmental Protection Agency, 1974. 2 v. (PB-229 816–PB-229 817)

Gainesville Municipal Waste Conversion Authority, Inc. Gainesville compost plant; an interim report. U.S. Department of Health, Education, and Welfare, 1969. 345 p. (PB-187 311)

Gainesville Municipal Waste Conversion Authority, Inc., and Environmental Engineering, Inc. Gainesville compost plant; final report on a solid waste management demonstration. v. 1-2. Environmental Protection Publication SW-21d. U.S. Environmental Protection Agency, 1973. 237 p. (PB-222 710)

Goddard, H. C. An economic evaluation of technical systems for scrap tire recycling. U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Dec. 1975. 48 p. (PB-249 197)

Great Lakes Research Institute. Evaluation, extraction, and recycling of certain solid waste components. Environmental Protection Publication SW-35d. U.S. Environmental Protection Agency, 1972. 110 p. (PB-208 674)

Gumtz, G. D., and E. J. Martin [Maryland Environmental Services]. Preliminary design of a comprehensive waste oil processing facility. U.S. Environmental Protection Agency, May 1975. 142 p. (PB-242 461)

Hansen, P. Residential paper recovery; a municipal implementation guide. Environmental Protection Publication SW-155. [Washington], U.S. Environmental Protection Agency, 1975. 26 p. (*AIM* no. 486)

Hansen, P., *comp.* Solid waste recycling projects; a national directory. Environmental Protection Publication SW-45. Washington, U.S. Government Printing Office, 1973. 284 p. (*AIM* no. 341)

Hansen, P., and J. Ramsey. Demonstrating multimaterial source separation in Somerville and Marblehead, Massachusetts. *Waste Age*, 7(2): 26-27, 48, Feb. 1976. (*AIM* no. 510)

Hart, S. A. Solid waste management/composting; European activity and American potential. Public Health Service Publication No. 1826. Washington, U.S. Government Printing Office, 1968. 40 p. (*AIM* no. 55)

Hecht, N. L., et al. Characterization and utilization of municipal and utility sludges and ashes. U.S. Environmental Protection Agency, May 1975. 3 v. (PB-244 309-Set)

v. 1. Hecht, N. L., and D. S. Duvall [University of Dayton Research Institute]. Summary. 40 p. (PB-244 310)

v. 2. Hecht, N. L., D. S. Duvall, and A. S. Rachidi [University of Dayton Research Institute]. Municipal sludges. 241 p. (PB-244 311)

v. 3. Hecht, N. L., and D. S. Duvall [University of Dayton Research Institute]. Utility coal ash. 74 p. (PB-244 312)

Herbert, W., and W. A. Flower. Glass and aluminum recovery in recycling operations. *Public Works*, 102(8):70,110,112, Aug. 1971. Reprinted, [Cincinnati], U.S. Environmental Protection Agency, 1972. 2 p. (*AIM* no. 308)

Herbert, W., and W. A. Flower. Waste processing complex emphasizes recycling. *Public Works*, 102(6):78-81, June 1971. Reprinted, [Cincinnati], U.S. Environmental Protection Agency, 1972. 4 p. (*AIM* no. 309)

Hinesly, T. D., O. C. Braids, and J. E. Molina. Agricultural benefits and environmental changes resulting from the use of digested sewage sludge on field crops; an interim report on a solid waste demonstration project. Environmental Protection Publication SW-30d. Washington, U.S. Government Printing Office, 1971. 62 p. (*AIM* no. 229)

Hortenstine, C. C., and D. F. Rothwell. Composted municipal refuse as a soil amendment. U.S. Environmental Protection Agency, 1973. 67 p. (PB-222 422)

Howard, S. E. Market locations for recovered materials. Environmental Protection Publication SW-518. [Washington], U.S. Environmental Protection Agency, Aug. 1976. 81 p. (*AIM* no. 518)

International Research and Technology Corporation. Tire recycling and reuse incentives. Environmental Protection Publication SW-32c. U.S. Environmental Protection Agency, 1974. 88 p. (PB-234 602)

Jensen, M. E. Observations of continental European solid waste management practices. Public Health Service Publication No. 1880. Washington, U.S. Government Printing Office, 1969. 46 p. (*AIM* no. 93)

Kelly, J. A. Radiolytic hydrolysis of cellulose. U.S. Environmental Protection Agency, 1973. 26 p. (PB-221 877)

Kennedy, J. C. Current concepts in the disposal of solid wastes. *Journal of Environmental Health*, 31(2):149-153, Sept.-Oct. 1968. (*AIM* no. 110)

Kiefer, I. The salvage industry; what it is–how it works. Environmental Protection Publication SW-29c.1. Washington, U.S. Government Printing Office, 1973. 32 p. [Condensation.] (*AIM* no. 333)

‡Kochtitzky, O. W., W. K. Seaman, and J. S. Wiley. Municipal composting research at Johnson City, Tennessee. *Compost Science*, 9(4): 5-16, Winter 1969. (*AIM* no. 74)

Leatherwood, J. M. Utilization of fibrous wastes as sources of nutrients. U.S. Environmental Protection Agency, 1973. 16 p. (PB-223 625)

Lefke, L. W. Progress in solid waste management and needed developments. *In* Proceedings; 8th Annual Environmental and Water Resources Engineering Conference, Nashville, June 5-6, 1969. Vanderbilt University, Technical Report No. 20. p. 107-118. Reprinted, [Cincinnati], U.S. Department of Health, Education, and Welfare, 1970. 16 p. (*AIM* no. 116)

Leonard S. Wegman Co., Inc. Marketability of recovered and clarified incinerator residue in the New York metropolitan area. Environmental Protection Publication SW-53d. U.S. Environmental Protection Agency, 1973. 188 p. (PB-222 588)

Levy, S. J. Materials recovery from post-consumer solid waste. Presented at 3d U.S.-Japan Conference on Solid Waste Management, Tokyo, May 12-14, 1976. Washington, U.S. Environmental Protection Agency. 33 p.

‡Lingle, S. A. Paper recycling in the United States. *Waste Age*, 5(8):6-8,10, Nov. 1974. (*AIM* no. 420)

Lingle, S. A. Paper recycling 1973; a dramatic year in perspective. *In* Fiber Conservation and Utilization: Proceedings; Pulp and Paper Seminar, Chicago, May 1974. Reprinted, San Francisco, Miller Freeman Publications, Inc., 1975. 11 p. (*AIM* no. 465)

†Lingle, S. A. Recycled materials markets; February 1975—a summary. Environmental Protection Publication SW-149. [Washington], U.S. Environmental Protection Agency, Apr. 1975. 8 p. (*AIM* no. 438)

Lingle, S. Separating paper at the waste source for recycling. Environmental Protection Publication SW-128. Washington, U.S. Government Printing Office, 1974. 16 p. (*AIM* no. 381)

‡Lossin, R. D. Compost studies. pt. I. *Compost Science*, 11(6):16-17, Nov.-Dec. 1970. (*AIM* no. 204)

‡Lossin, R. D. Compost studies, pt. II. *Compost Science*, 12(1):12-13, Jan.-Feb. 1971. (*AIM* no. 205)

‡Lossin, R. D. Compost studies, pt. III. Measurement of the chemical oxygen demand of compost. *Compost Science*, 12(2):31-32, Mar.-Apr. 1971. (*AIM* no. 206)

McGauhey, P. H. American composting concepts. Public Health Service Publication No. 2023. Washington, U.S. Government Printing Office, 1971. 23 p. (*AIM* no. 169)

McGough, E. Recycling our resources. *American Youth*, 13(1):18-21, Mar.-Apr. 1972. (*AIM* no. 273)

Maizus, S. [National Oil Recovery Corporation]. Recycling of waste oils. U.S. Environmental Protection Agency, June 1975. 283 p. (PB-243 222)

Malisch, W. R., D. E. Day, and B. G. Wixson. Use of domestic waste glass for urban paving. U.S. Environmental Protection Agency, 1973. 107 p. (PB-222 052)

Malisch, W. R., D. E. Day, and B. G. Wixson [University of Missouri]. Use of domestic waste glass for urban paving; summary report. U.S. Environmental Protection Agency, May 1975. 60 p. (PB-242 536)

Management Technology, Inc. Automobile scrapping processes and needs for Maryland; a final report on a solid waste demonstration. Public Health Service Publication No. 2027. Washington, U.S. Government Printing Office, 1970. 64 p. (*AIM* no. 106)

Marceleno, T. The processing and recovery of Jon Thomas—cool cat! Washington, U.S. Government Printing Office, 1972. 34 p. (*AIM* no. 299)

Martin, E. J., and G. D. Gumtz [Environmental Quality Systems, Inc.]. State of Maryland waste oil recovery and reuse program. Washington, U.S. Environmental Protection Agency, Jan. 1974. 262 p. (PB-234 446)

Meller, F. H. Conversion of organic solid wastes into yeast; an economic evaluation. Public Health Service Publication No. 1909. Washington, U.S. Government Printing Office, 1969. 173 p. (*AIM* no. 91)

†National Academy of Engineering—National Academy of Sciences. Policies for solid waste management. Public Health Service Publication No. 2018. Washington, U.S. Government Printing Office, 1970. 64 p. (*AIM* no. 112)

National Center for Resource Recovery. Residential paper recovery: a community action program. Washington, U.S. Environmental Protection Agency, 1976. (In preparation.)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

Neff, N. T. [A. M. Kinney, Inc.]. Solid waste and fiber recovery demonstration plant for the City of Franklin, Ohio; an interim report. Environmental Protection Publication SW-47d.i. U.S. Environmental Protection Agency, 1972. 83 p. (PB-213 646)

Nelson, R. D., and E. Vey [IIT Research Institute]. Reuse of solid waste from water-softening processes. U.S. Environmental Protection Agency, 1973. 108 p. (PB-224 820)

Opferkuch, R. E., et al. Study of utilization and disposal of lime sludges containing phosphates. U.S. Environmental Protection Agency, 1973. 119 p. (PB-222 354)

†Peterson, M. L. Parasitological examination of compost; a Solid Waste Research open-file report. [Cincinnati], U.S. Environmental Protection Agency, 1971. 15 p. (*AIM* no. 224)

Pettigrew, R. J., F. H. Roninger, W. J. Markiewicz, and M. J. Gransky. Rubber reuse and solid waste management. pt. 1-2. [Public Health Service Publication No. 2124.] Washington, U.S. Government Printing Office, 1971. 120 p. (*AIM* no. 187)

Recycle; in search of new policies for resource recovery. League of Women Voters Publication No. 132. Washington, League of Women Voters of the United States, 1972. 39 p. (*AIM* no. 296)

Recycling and the consumer; solid waste management. Environmental Protection Publication SW-117. [Washington], U.S. Environmental Protection Agency, 1974. 12 p. (*AIM* no. 344)

Recycling and the consumer; solid waste management. Environmental Protection Publication SW-117.1. [Washington], U.S. Environmental Protection Agency, 1974. [16¾ x 22-in. two-sided sheet with information about recycling as well as illustrations of five recyclable materials, which can be made into a mobile.] (*AIM* no. 403)

Regan, R., et al. Cellulose degradation in composting. U.S. Environmental Protection Agency, 1973. 153 p. (PB-215 722)

Regan, W. J., R. W. James, and T. J. McLeer [Institute of Scrap Iron and Steel, Inc.]. Identification of opportunities for increased recycling of ferrous solid waste. Environmental Protection Publication SW-45d. U.S. Environmental Protection Agency, 1972. 391 p. (PB-213 577)

Resource Planning Associates, Inc. Source separation: the community awareness program in Somerville and Marblehead, Massachusetts. Environmental Protection Publication SW-551. Washington, U.S. Environmental Protection Agency, 1976. 81 p. (*AIM* no. 551)

Resource Planning Institute. A case study and business analysis of the scrap industry. U.S. Environmental Protection Agency, 1974. 129 p. (PB-229 220)

‡Rogers, C. J., P. V. Scarpino, E. Coleman, D. F. Spino, and T. C. Purcell. Production of fungal protein from cellulose and waste cellulosics. *Environmental Science & Technology*, 6(8): 715-719, Aug. 1972. (*AIM* no. 295)

Roig, R. W., et al. [International Research and Technology Corporation]. Impacts of material substitution in automobile manufacture on resource recovery. U.S. Environmental Protection Agency, 1975. 2 v. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Ruf, J. A. Refuse shredders at EPA's Gainesville, Florida, experimental composting plant. *Waste Age*, 5(3):58,60-63,66, May/June 1974. (*AIM* no. 402)

SCS Engineers, Inc. Analysis of source separate collection of recyclable solid waste; separate collection studies. [v. 1.] Environmental Protection Publication SW-95c.1. U.S. Environmental Protection Agency, 1974. 157 p. (PB-239 775)

SCS Engineers, Inc. Analysis of source separate collection of recyclable solid waste; collection center studies. v. 2. Environmental Protection Publication SW-95c.2. U.S. Environmental Protection Agency, 1974. 75 p. (PB-239 776)

SCS Engineers, Inc. Evaluation of a compartmentalized refuse collection vehicle for separate newspaper collection. U.S. Environmental Protection Agency, May 1976. 97 p. (PB-257 969)

SCS Engineers, Inc. Optimization of office paper recovery systems; final report. U.S. Environmental Protection Agency, 1976. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Shafizadeh, F., et al. Chemical conversion of wood and cellulosic wastes. U.S. Environmental Protection Agency, 1974. 60 p. (PB-229 246)

Shell, G. L., and J. L. Boyd. Composting dewatered sewage sludge. Public Health Service Publication No. 1936. Washington, U.S. Government Printing Office, 1970. 28 p. (*AIM* no. 115)

Smith, F. L., Jr. Trends in wastepaper exports and their effects on domestic markets. Environmental Protection Publication SW-132. [Washington], U.S. Environmental Protection Agency, 1974. 17 p. (*AIM* no. 397)

Smith, F. L., Jr. Wastepaper recycling: review of recent market demand and supply. *Pulp & Paper*, 49(10):148-151, Sept. 1975. (*AIM* no. 511)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

Solid Waste Engineering and Transfer Systems, Inc. Economic feasibility study, second phase; resource recovery facility, San Francisco solid waste transfer station. U.S. Environmental Protection Agency, 1974. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

†Solid waste reduction/salvage plant, an interim report; City of Madison pilot plant demonstration project, June 14 to December 31, 1967. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 25 p. (*AIM* no. 57)

‡Stearns, R. P., and R. H. Davis. The economics of separate refuse collection. *Waste Age*, 5(3):6-8,10-11, 14-15,130-131, May/June 1974. (*AIM* no. 400)

Stevenson, M. K., J. O. Leckie, and R. Eliassen. Preparation and evaluation of activated carbon produced from municipal refuse. U.S. Environmental Protection Agency, 1973. 150 p. (PB-221 172)

Stone, R. B., C. C. Buchanan, and F. W. Steimle, Jr. Scrap tires as artificial reefs. Environmental Protection Publication SW-119. Washington, U.S. Government Printing Office, 1974. 33 p. (*AIM* no. 348)

Stone, G. E., and C. C. Wiles. Composting at Johnson City; final report on joint USEPA-TVA composting project with operational data, 1967 to 1971. v. 1-2. Environmental Protection Publication SW-31r.2. [Washington], U.S. Environmental Protection Agency, 1975. 336 p. (*AIM* no. 488)

Stuart Finley, Inc. Recycling. Environmental Protection Publication SW-39c.3. [Cincinnati], U.S. Environmental Protection Agency, 1972. 8 p. [Film narrative.] (*AIM* no. 268)

‡Stutzenberger, F. J., A. J. Kaufman, and R. D. Lossin. Cellulolytic activity in municipal solid waste composting. *Canadian Journal of Microbiology*, 16(7):553-560, July 1970. (*AIM* no. 126)

Systems Technology Corporation. A technical, environmental and economic evaluation of the "wet processing system for the recovery and disposal of municipal solid waste." Environmental Protection Publication SW-109c. U.S. Environmental Protection Agency, 1975. 223 p. (PB-245 674)

Talley, R. J., and R. H. Ongerth. Aluminum as a component of solid waste and a recoverable resource. U.S. Environmental Protection Agency, 1974. 31 p. (PB-235 770)

U.S. Environmental Protection Agency. Promulgation resource recovery facilities guidelines. *Federal Register*, 41(184):41208-41211, Sept. 21, 1976. (*AIM* no. 490)

U.S. Environmental Protection Agency. Source separation for materials recovery; guidelines. *Federal Register*, 41(80):16950-16956, Apr. 23, 1976. (*AIM* no. 473)

U.S. Environmental Protection Agency, Federal solid waste management program. The automobile cycle: an environmental and resource reclamation problem. Environmental Protection Publication SW-80ts.1. Washington, U.S. Government Printing Office, 1972. 115 p. (*AIM* no. 275)

‡Vaughan, R. D. Recycling and reuse of waste materials; an essential feature of solid waste control systems for the future. *Waste Age*, 1(1): 6-7, Sept. 1969. (*AIM* no. 96)

†Vaughan, R. D. Reuse of solid wastes: a major solution to a major national problem. *Waste Age*, 1(1): 10,14-15, Apr. 1970. (*AIM* no. 119)

Weinberg, M. S., et al. Sludge conditioning using sulfur dioxide and low pressure for production of organic feed concentrate. U.S. Environmental Protection Agency, 1973. 90 p. (PB-223 343)

Weinstein, N. J. Waste oil recycling and disposal. U.S. Environmental Protection Agency, 1974. 328 p. (PB-235 857)

What you can do to recycle more paper. Environmental Protection Publication SW-143. [Washington], U.S. Environmental Protection Agency, 1975. 12 p. (*AIM* no. 446)

Wiley, J. S. Composting of organic wastes; an annotated bibliography. Suppl. 1. U.S. Department of Health, Education, and Welfare, Technical Development Laboratories, June 1959. 65 p. (PB-147 220)

Wiley, J. S. Composting of organic wastes; an annotated bibliography. Suppl. 2. U.S. Department of Health, Education, and Welfare, Communicable Disease Center, Apr. 1960. 66 p. (PB-148 097)

‡Wiley, J. S. Some specialized equipment used in European compost systems. *Compost Science*, 4(1): 7-10, Spring 1963. (*AIM* no. 61)

Wiley, J. S., F. E. Gartrell, and H. G. Smith. Concept and design of the joint U.S. Public Health Service-Tennessee Valley Authority composting project, Johnson City, Tennessee. [Cincinnati], U.S. Department of Health, Education, and Welfare, 1968. 14 p. (*AIM* no. 9)

---

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

Wiley, J. S., and O. W. Kochtitzky. Composting developments in the United States. *Compost Science,* 6(2):5-9, Summer 1965. [Reprinted, Washington, U.S. Government Printing Office, 1968.] 5 p. (*AIM* no. 8)

Wolk, R. H., and C. A. Battista. Study of the technical and economic feasibility of a hydrogenation process for utilization of waste rubber. U.S. Environmental Protection Agency, 1973. 155 p. (PB-222 694)

VI. ENERGY RECOVERY FROM WASTE

Arthur D. Little, Inc. Study of the feasibility of Federal procurement of fuels produced from solid wastes. Environmental Protection Publication SW-123c. U.S. Environmental Protection Agency, July 1975. 256 p. (PB-255 695)

Ayer, F. A., *comp.* [Research Triangle Institute]. Symposium on Environment and Energy Conservation (November 1975, Denver, Colorado). U.S. Environmental Protection Agency and U.S. Energy Research and Development Administration, Aug. 1976. 512 p. (To be distributed by National Technical Information Service, Springfield, Va.)

Combustion Power Company, Inc. Combustion power unit-400 (CPU-400); a technical abstract. U.S. Department of Health, Education, and Welfare, 1969. 15 p. (PB-187 299)

Engdahl, R. B., [Battelle Columbus Laboratories]. Identification of technical and operating problems of Nashville Thermal Transfer Corporation waste-to-energy plant. U.S. Energy Research and Development Administration, Feb. 25, 1976. 35 p. (BMI-1947)

EPA press briefing on solid waste management and energy, February 8, 1974. [Washington], U.S. Environmental Protection Agency, 1974. 6 p., attachments, app. (*AIM* no. 359)

Hitte, S. J. Anaerobic digestion of solid waste and sewage sludge to methane. Environmental Protection Publication SW-159. [Washington], U.S. Environmental Protection Agency, July 1975. 13 p. (*AIM* no. 458)

Hoffman, D. A. Pyrolysis of solid municipal wastes. U.S. Environmental Protection Agency, 1973. 78 p. (PB-222 015)

Holloway, J. R. Resource recovery technology update from the U.S.E.P.A.; EPA resource recovery demonstration: summary of air emissions analyses. *Waste Age,* 7(8):50-52, Aug. 1976. (*AIM* no. 538)

Horner and Shrifrin, Inc. Energy recovery from waste; a municipal-utility joint venture. Environmental Protection Publication SW-36d.i. Washington, U.S. Environmental Protection Agency, 1972. 20 p. (PB-213 534)

Horner and Shifrin, Inc. Solid waste as fuel for power plants. Environmental Protection Publication SW-36d. U.S. Environmental Protection Agency, 1973. 146 p. (PB-220 316)

Huffman, G. L. The EPA R&D program in wastes-as-fuel: an overview focusing on process environmental/energy impacts. *In* F. A. Ayer, *comp.,* Symposium on Environment and Energy Conservation (November 1975, Denver, Colorado). U.S. Environmental Protection Agency and U.S. Energy Research and Development Administration, Aug. 1976. p. 422-434. (To be distributed by National Technical Information Service, Springfield, Va.)

Huffman, G. L. Processes for the conversion of solid wastes and biomass fuels to clean energy forms. *In* Proceedings; A Conference on Capturing the Sun Through Bioconversion, Washington, Mar. 10-12, 1976. Washington, Washington Center for Metropolitan Studies. p. 454-484

Kaufman, J. A., and A. H. Weiss. Solid waste conversion: cellulose liquefaction. U.S. Environmental Protection Agency, 1975. 216 p. (PB-239 509)

Levy, S. J. The conversion of municipal solid waste to a liquid fuel by pyrolysis. *In* Conference Papers; CRE; Conversion of Refuse to Energy; 1st International Conference and Technical Exhibition, Montreux, Switzerland, Nov. 3-5, 1975. IEEE cat. no. 75CH1008-2 CRE. [Piscataway, N. J.], Institute of Electrical and Electronics Engineers. p. 226-231.

Levy, S. J. Markets and technology for recovering energy from solid waste. Environmental Protection Publication SW-130. Washington, U.S. Environmental Protection Agency, 1974. 31 p. (*AIM* no. 401)

†Levy, S. J. Pyrolysis of municipal solid waste. *Waste Age,* 5(7):14-15,17-20, Oct. 1974. (*AIM* no. 417)

Levy, S. J. Pyrolysis of solid waste. *In* Recent Developments in Resource Recovery; Seminar Proceedings, Hull, Quebec, Mar. 7, 1974. Solid Waste Management Report EPS-3-EP-74-3. [Ottawa], Environment Canada, Ecological Protection Branch, June 1974. p. 48-74.

Levy, S. J. A review of the status of pyrolysis as a means of recovering energy from municipal solid waste. Presented at 3d U.S.-Japan Conference on Solid Waste Management, Tokyo, May 12-14, 1976. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. 29 p.

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†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

Levy, S. J. San Diego County demonstrates pyrolysis of solid waste to recover liquid fuel, metals, and glass. Environmental Protection Publication SW-80d.2. Washington, U.S. Government Printing Office, 1975. 27 p. (*AIM* no. 442)

Lowe, R. A. Energy recovery from waste; solid waste as supplementary fuel in power plant boilers. Environmental Protection Publication SW-36d.ii. Washington, U.S. Government Printing Office, 1973. 24 p. (*AIM* no. 264)

Lowe, R. A. Use of solid waste as a fuel by investor-owned electric utility companies. *In* Proceedings; EPA/Edison Electric Institute Meeting, Washington, Mar. 5-6, 1975. Environmental Protection Publication SW-6p. Reprinted, [Washington], U.S. Environmental Protection Agency, 1975. 27 p. (*AIM* no. 467)

McEwen, L. B., and S. J. Levy. Can Nashville's story be placed in perspective? *Solid Wastes Management/Refuse Removal Journal,* 19(8):24, 28-30,58,60, Aug. 1976. (*AIM* no. 548)

Metcalf & Eddy, Inc., and City of Lynn, Massachusetts. Generation of steam from solid wastes. Environmental Protection Publication SW-49d. U.S. Environmental Protection Agency, 1972. 139 p. (PB-214 166)

Nydick, S. E., and J. R. Hurley [Thermo-Electron Corporation]. Solid waste as a supplementary fuel in industrial boilers. U.S. Environmental Protection Agency, 1976. (In press; to be distributed by National Technical Information Service, Springfield, Va.)

Pfeffer, J. T. Reclamation of energy from organic waste. U.S. Environmental Protection Agency, 1974. 143 p. (PB-231 176)

Proceedings; A Conference on Capturing the Sun Through Bioconversion, Washington, Mar. 10-12, 1976. Washington, Washington Center for Metropolitan Studies. 862 p.

†Pyrolysis: a possible new approach to solid waste disposal and recycling. [Cincinnati, U.S. Environmental Protection Agency], May 1973. 4 p. (*AIM* no. 329)

RECON Systems, Inc. Municipal-scale thermal processing of solid wastes. U.S. Environmental Protection Agency, 1976. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Roberts, R. M., et al. [Envirogenics Company]. Systems evaluation of refuse as a low sulfur fuel. U.S. Environmental Protection Agency, Nov. 1971. 2 v. (PB-209 271–PB-209 272)

Saving the energy in solid waste; environmental information. Washington, U.S. Environmental Protection Agency, [1976]. 4 p. (*AIM* no. 503)

Shannon, L. J., D. E. Fiscus, and P. G. Gorman. St. Louis refuse processing plant; equipment, facility, and environmental evaluations; final report, Sept. 1974-Jan. 1975. U.S. Environmental Protection Agency, May 1975. 122 p. (PB-243 634)

Shannon, L. J., et al. [Midwest Research Institute]. St. Louis/Union Electric refuse firing demonstration air pollution test report. U.S. Environmental Protection Agency, Aug. 1974. 119 p. (PB-237 630)

Sussman, D. B. Baltimore demonstrates gas pyrolysis; resource recovery from solid waste. Environmental Protection Publication SW-75d.i. Washington, U.S. Government Printing Office, 1975. 24 p. (*AIM* no. 431)

[Sussman, D. B.] Resource recovery technology update from the U.S.E.P.A.; Baltimore pyrolysis and waste-fired steam generator emissions. *Waste Age,* 7(7):6-9,77, July 1976. (*AIM* no. 537)

Sutterfield, G. W. Refuse as a supplementary fuel for power plants; November 1973 through March 1974; interim progress report. Environmental Protection Publication SW-36d.iii. [Washington], U.S. Environmental Protection Agency, July 1974. 25 p. (*AIM* no. 387)

Truett, B., R. G. Murray, and G. Foley [Stanford Research Institute and Mitre Corp.]. EPA program status report—synthetic fuels program. U.S. Environmental Protection Agency, Oct. 1975. 32 p. (PB-247 140)

Tunnah, B. G., A. Hakki, and R. J. Leonard [Gordian Associates, Inc.]. Where the boilers are; a survey of electric utility boilers with potential capacity for burning solid waste as fuel. Environmental Protection Publication SW-88c. U.S. Environmental Protection Agency, 1974. 329 p. (PB-239 392)

Ware, S. A. [Ebon Research Systems]. State-of-the-art of bioconversion as a waste processing alternative in the U.S. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service.)

Wilson, E. M., and H. M. Freeman. Processing energy from wastes. *Environmental Science & Technology,* 10(5):430-435, May 1976.

‡Wisely, F. E., G. W. Sutterfield, and D. L. Klumb. St. Louis power plant to burn city refuse. *Civil Engineering,* 41(1):56-59, Jan. 1971. (*AIM* no. 180)

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†Out of print; available only from EPA libraries or Government Printing Office depository libraries.

‡Available in public and university libraries.

VII. POLICY STUDIES AND PAPERS

Anderson, R. C., and R. D. Spiegelman [Environmental Law Institute]. The impact of the Federal tax code on resource recovery. U.S. Environmental Protection Agency, 1976. (In press; to be distributed by National Technical Information Service, Springfield, Va.)

Anderson, T., et al. The states' roles in solid waste management; a task force report. Lexington, Ky., Council of State Governments, Apr. 1973. 58 p. Reprinted, [Cincinnati], U.S. Environmental Protection Agency, May 1973. (*AIM* no. 327)

Arthur D. Little, Inc. Incentives for recycling and reuse of plastics; a summary report. Environmental Protection Publication SW-41c.1. [Cincinnati], U.S. Environmental Protection Agency, 1973. 18 p. (*AIM* no. 316)

Bingham, T. H., and P. F. Mulligan [Research Triangle Institute]. The beverage container problem; analysis and recommendations. U.S. Environmental Protection Agency, Sept. 1972. 190 p. (PB-213 341)

Bingham, T. H., et al. [Research Triangle Institute]. An evaluation of the effectiveness and costs of regulatory and fiscal policy instruments on product packaging. Environmental Protection Publication SW-74c. [Washington], U.S. Environmental Protection Agency, 1974. 301 p. (*AIM* no. 437)

Booz-Allen and Hamilton, Inc. An evaluation of the impact of discriminatory taxation on the use of primary and secondary raw materials. Environmental Protection Publication SW-101c. U.S. Environmental Protection Agency, 1975. 148 p. (PB-240 988)

Cardin, F. A. Secondary fiber recovery incentive analysis. U.S. Environmental Protection Agency, National Environmental Research Center, Oct. 1974. 400 p. (PB-241 082)

Cities and the nation's disposal crisis. Washington, National League of Cities and U.S. Conference of Mayors, Mar. 1973. 46 p. Reprinted, [Cincinnati], U.S. Environmental Protection Agency, June 1973. (*AIM* no. 331)

Ernst & Ernst. An investigation of consumer demand elasticities. U.S. Environmental Protection Agency. 3 v. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

International Research and Technology Corporation. Problems and opportunities in management of combustible solid wastes. U.S. Environmental Protection Agency, 1973. 517 p. (PB-222 467)

Irwin, W. A., and R. A. Liroff [Environmental Law Institute]. Economic disincentives for pollution control: legal, political, and administrative disincentives. U.S. Environmental Protection Agency, July 1974. 271 p. (PB-239 340)

Kiefer, I. Incentives for tire recycling and reuse. Environmental Protection Publication SW-32c.1. Washington, U.S. Government Printing Office, 1974. 28 p. (*AIM* no. 382)

Loube, M. Beverage containers: the Vermont experience. Environmental Protection Publication SW-139. [Washington], U.S. Environmental Protection Agency, 1975. 16 p. (*AIM* no. 487)

Milgrom, J. Can Federal procurement practices be used to reduce solid wastes? U.S. Environmental Protection Agency, 1974. 232 p. (PB-229 727)

Milgrom, J. Incentives for recycling and reuse of plastics. Environmental Protection Publication SW-41c. U.S. Environmental Protection Agency, 1972. 316 p. (PB-214 045)

Moshman Associates, Inc. Transportation rates and costs for selected virgin and secondary commodities. U.S. Environmental Protection Agency, 1974. 234 p. (PB-233 871)

Questions and answers; returnable beverage containers for beer and soft drinks. [Washington, U.S. Environmental Protection Agency], July 1975. 13 p. (*AIM* no. 462)

Rains, W. A., and D. E. Williams [Smithers Scientific Service, Inc.]. A study of the feasibility of requiring the Federal Government to use retreaded tires. Environmental Protection Publication SW-105c. U.S. Environmental Protection Agency, 1975. 122 p. (PB-243 028)

Ramsey, J. M. [Resource Planning Associates]. Requiring secondary materials in Federal construction; a feasibility study. Environmental Protection Publication SW-130c. U.S. Environmental Protection Agency, Jan. 1975. 206 p. (PB-241 729)

Resource Planning Associates. Implementation and enforcement of Federal consumer product regulatory programs; final report. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Feb. 28, 1974. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Resource Planning Associates. A study of Federal subsidies to stimulate resource recovery. Environmental Protection Publication SW-96c. U.S. Environmental Protection Agency, 1974. [144 p.] (PB-239 736)

SCS Engineers. Analysis of Federal programs affecting solid waste generation and recycling. U.S. Environmental Protection Agency, 1972. 153 p. (PB-213 311)

Slitor, R. E. Administrative aspects of a dedicated manufacturers excise tax on solid waste creating products; final report. U.S. Environmental Protection Agency, Resource Recovery Division. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

State solid waste management and resource recovery incentives act. *In* 1973 Suggested state legislation. v. 32. Lexington, Ky., The Council of State Governments, 1973. Reprinted, [Washington], U.S. Environmental Protection Agency, 1974. p. 63-76. (*AIM* no. 377)

Stevens, B. H. Criteria for regional solid waste management planning. U.S. Environmental Protection Agency, 1974. 338 p. (PB-239 631)

Appendix D

LISTING OF MAJOR U.S. GOVERNMENT AGENCY RESEARCH PROJECTS AND STUDIES

This is a list of research and development projects and studies in the area of resource recovery and waste reduction that were in progress as of September 1976 in the following Federal agencies:

U.S. Environmental Protection Agency (Office of Solid Waste and Office of Research and Development)
U.S. Department of Commerce
U.S. Department of Interior, Bureau of Mines
U.S. Energy Research and Development Administration
Federal Energy Administration

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U.S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF SOLID WASTE:					
Virgin Material Charges: A Theoretical and Empirical Evaluation in the Paper Industry Analysis of the ramifications of a raw materials charge/subsidy policy applied to the paper industry.	Contract (68-01-3267)	Research Triangle Institute, Research Triangle Park, N. C.	$49,767	6/9/75	Draft final report under review
Environmental Impact of Disposables vs. Reusables Evaluation of the environmental and resource consumption impacts of nine disposable/reusable products, including towels, napkins, bedding, diapers, drinking containers, and plates. Health and economic issues associated with the use of these products will be investigated.	Contract (68-01-2995)	Midwest Research Institute, Kansas City, Mo.	$121,999	11/19/74	Final report in preparation

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF SOLID WASTE (CONTINUED):					
Glass Recovery Technology Comparative economic analysis of current mechanical glass recovery systems.	Contract (68-01-1966)	Raytheon Company, Burlington, Mass.	$ 9,790	3/5/76	Draft final report under review
Implementation Manual for Office Wastepaper Recovery Systems A how-to-do-it guide.	Contract (68-01-3596)	Stearns, Conrad & Schmidt, Engineers, Long Beach, Calif.	$ 24,800	3/18/76	9/17/76 In preparation
Materials Recovery Systems, A Technical and Economic Analysis An evaluation of the New Orleans resource recovery facility.	Contract (68-01-2944)	National Center for Resource Recovery, Washington, D. C.	$ 61,161	12/10/76	Contract not yet awarded
Resource and Environmental Profile Analysis of Five Milk Containers Evaluation of the environmental and resource consumption impacts of five milk containers: refillable glass bottle and plastic bottle, nonrefillable plastic bottle, paperboard carton, and plastic pouch. Various sizes of each container type will be evaluated. Health and economic issues associated with the use of each container type will be investigated.	Contract (68-01-2953)	Midwest Research Institute, Kansas City, Mo.	$ 64,905	9/30/74	Draft final report under review
Resource Recovery Plant Implementation Process Case Studies A review of the experiences of six communities in implementing a resource recovery facility, with particular attention to control of the supply of waste, establishment of markets, identification of economics, obtaining financing, and elements of the planning process.	Contract (68-01-3422)	Development Sciences, Inc., East Sandwich, Mass.	$ 49,958	4/5/76	12/30/76
Technical Assessment Support Provides technical support to the Technology and Markets Branch in evaluating specific technical issues. This has included an evaluation of resource recovery technology.	Contract (68-01-3285)	Systems Technology Corporation, Dayton, Ohio	$ 41,122	6/26/75	Contract to be extended

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF SOLID WASTE (CONTINUED):					
Technical Assistance Support To provide support to the Technical Assistance Branch in aiding local, State, and Federal programs on implementation of resource recovery facilities.	Contract (RFP No. WA-76-R164)	To be selected	$290,000	N.A.	N.A.
Evaluation of European Waterwall Incinerator Design Practices Assessment of the technology as it pertains to use in the United States.	Contract (No. 68-01-4376)	Battelle Columbus Lab.	$200,000 (est.)	10/1/76 (est.)	10/1/78
Interpreting Cost Data for RDF Solid Waste Resource Recovery Systems: A Guide for Local Government Decision-Makers An analysis of cost variables in the construction and operation of RDF systems.	Contract (RFP No. WA-76-B135)	Raytheon Service Co.	$100,000	10/15/76	10/15/77
Technical and Economic Evaluation of the EPA Demonstration (Resource Recovery) Project in Baltimore, Maryland A technical, economic, and environmental evaluation of the gas pyrolysis plant in Baltimore. Includes history of scale-up and start-up anomalies; evaluation of air emissions, dust emissions, effluent water quality; analysis of products and economic viability.	Contract (68-01-4359)	Systems Technology Corp.	$350,000 (est.)	10/1/76 (est.)	10/1/78
Technical and Economic Evaluation of the EPA Demonstration (Resource Recovery) Project in San Diego, California A technical, economic, and environmental evaluation of the solid waste oil pyrolysis plant in San Diego.	Contract (RFP No. WA-76-B392)	To be selected	$400,000 (est.)	12/1/76 (est.)	Proposals under review
Estimates of the Transitional Impacts on Beverage Prices and Other Costs and Benefits of National Beverage Container Legislation.	Contract ✓ (68-01-3420 A)	Research Triangle Institnte, Research Triangle Park, N.C.	$50,000	3/8/76	12/31/77
Analysis of the Interrelationships Between Beverage Containers and Structural Change in the Brewing and Soft Drink Industries. Analysis of the interrelationships between alternative container types and such factors as firm size, employment, skill mix,	Contract ✓ (68-01-3420 B)	Research Triangle Instutute, Research Triangle Park, N.C.	$50,000	3/8/76	12/31/77

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U.S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF SOLID WASTE (CONTINUED):					
and geographical location in the brewing and soft drink manufacturing industries.					
Appraisal of the Impacts of Beverage Container Guidelines on Specific Beverage Producers and Distributors.	Contract ✓ (68-01-3420 C)	Research Triangle Institute, Research Triangle Park, N.C.	$50,000	3/8/76	6/30/77
Analysis of Charge/Subsidy Policies Applied to Rigid Container Materials. Development of estimates and methods for estimating the impact of various possible financial incentives on materials production, recycling, and solid waste generation associated with steel, glass, aluminum, and plastic materials used in rigid containers.	Contract ✓ (68-01-3426)	Research Triangle Institute, Research Triangle Park, N.C.	$38,950	7/6/76	10/77
Prices of Personal Consumption Items. Develop methods and produce estimates of the effect on household budgets in different income groups of a solid waste product charge on the material content of consumer goods.	Contract ✓ (68-01-3429)	Research Triangle Institute, Research Triangle Park, N.C.	$35,990	7/6/76	10/77
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO:					
Construction and Demolition Wastes Survey Complete survey report on energy potential of major demolition wastes in 10 of the top 20 cities, based on extrapolations from demolition business volume.	Contract (68-01-3560)	JACA Associates	$ 83,000	1/76	5/77
Agricultural and Forestry Wastes Survey Review of availability of wastes and estimate of pollutant potential using NSF data bank to determine feasibility of using agricultural and forestry wastes as fuels or feedstocks for energy conversion processes.	Contract (68-01-2946)	Stanford Research Institute	$ 60,000	7/76	4/77

U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
Municipal Solid Waste Survey Protocol Complete development of a protocol for determining the composition and total quantities of municipal refuse for design of resource recovery plants.	Contract (RFP No. CI-76-0241)	To be selected	N. A.	10/76	4/78
Preprocessing Systems Evaluation Evaluate actual systems and equipment for preparing refuse-derived fuels and feedstocks for energy recovery systems through field tests.	Contract (68-03-2387)	Midwest Research Institute	$349,000	3/76	10/78
Municipal Solid Waste Pre-Processing Research and Development The NCRR Environmental Test and Evaluation Facility (large-scale pilot plant) will be used to study the operation of specific unit processes and systems configurations for the recovery of materials and fuel fraction from MSW.	Grant (803901)	National Center for Resource Recovery	$340,000	9/8/75	7/77
Fine Grinding Technology Development The requirements for fine grinding of MSW for resource recovery processes are being investigated, especially for energy conversion processes. Research efforts will attempt to expand fine grinding theory to include the fine particle range. Comparative evaluations of equipment for fine grinding will be made.	Grant (R-804034)	University of California	$175,000	8/75	12/77
Preparation of Densified RDF Develop and evaluate a process for the preparation of d-RDF from municipal solid waste. Determine the properties of the fuel.	Grant (R-804150)	National Center for Resource Recovery	$270,000	9/75	4/78
Concepts for Improving the Fuel Quality of RDF Thermochemical preprocessing technology as used in other	Grant (R-804421)	University of Dayton Research Institute	$112,000	8/76	9/78

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U.S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
fields will be explored for applicability. Develop selected processes as warranted by feasibility.					
Preprocessing System Optimization Prepare a survey report assessing performance information needs for resource recovery preprocessing system optimization. Design a complete program, considering selected alternative approaches, which will lead to the development of optimal preprocessing systems for large and small communities.	Contract (RFP)	To be selected	N. A.	10/76 (est.)	10/77 (est.)
St. Louis/Union Electric Supplementary Fuel Studies Research, development, and demonstration studies are continuing to determine the environmental and technological aspects of co-firing RDF with coal in a suspension (tangential) fired utility boiler. Hazardous emission tests are included. Continuation of this work will investigate in detail the question of virus and bacteria emissions from the preprocessing facility and compare the emissions to those associated with sewage treatment plants, transfer stations, and landfills.	Contract (68-02-1871)	Midwest Research Institute	$242,000	9/76	7/77
Utilization of Solid Waste as a Supplementary Power Plant Fuel Studies of the technical aspects of firing RDF (fluff) with coal in a stoker utility boiler, emphasizing high RDF loadings, corrosion effects, and environmental pollution. This study has produced highly significant information regarding corrosion aspects.	Grant (804008)	City of Columbus, Battelle/Columbus	$410,000	6/74	3/79
County of Hawaii Project The County will evaluate the feasibility of alternative	Grant (803924)	County of Hawaii	$ 50,000	12/75	12/76 Draft report under review

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
waste disposal tools. Emphasis will be placed on coincineration of MSW with agricultural wastes in existing bagasse boilers available at selected sugar manufacturing sites.					
Waste as a Supplementary Fuel: Co-firing With Coal and Gas This study will evaluate an advanced RDF plant and co-firing of the RDF with coal and gas in a tangentially fired boiler. Technical, economic, and environmental data will be generated and evaluated, including data not available from the St. Louis study.	Grant (803903)	City of Ames, Iowa	$465,000	12/75	7/78
Firing Densified-RDF in a Stoker Boiler Evaluations of technical, economic, and environmental aspects of co-firing d-RDF with lump coal in stoker boilers with emphasis on applicability to smaller communities.	Contract (68-03-2426)	Systems Technology Corp.	$293,000	7/76	12/77
Portable Pyrolysis of Agricultural Wastes Assess the technical feasibility and economic viability of pyrolyzing agricultural wastes in a portable unit to provide a source of sulfur-free gas or fuel oil, and other energy products, such as char, that can be more easily transported, thereby saving more than 75% of the transportation costs.	Grant	Georgia Institute of Technology	$204,000	5/74	6/77
Pilot Pyrolysis of Mixed Waste to Fuel Use small-batch pyrolyzer and pilot-size (200 kg/hr) fluidized bed pyrolyzer to determine fraction of fuel products (i.e., gas, liquid and solid) produced in the pyrolysis of various types and mixes of solid wastes (i.e., municipal, agricultural, industrial, etc.), as a function of the pyrolyzing conditions.	Contract	Energy Resources Co., Inc.	$565,000	6/75	9/77

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
Biological Conversion Process Assessment and Development Comprehensive evaluations of major bioconversion waste-to-energy processes, including preprocessing requirements, process technology, environmental aspects, and pollution control needs. Research recommendations will be made for systems identified as promising candidates for development.	Grant (804457)	Oasis 2000	$110,000	8/76	9/77
A Case Study of Methane Recovery from a Sanitary Landfill A case study of the Palos Verdes landfill gas development project, including methods to optimize the production and recovery of methane.	Contract (68-03-2143)	CDM Inc., Environmental Engineering	$ 20,000	9/75	9/76 Draft report under review
Evaluate Enzymatic Hydrolysis and Subsequent Conversion to Produce an Ethanol-Based Fuel Studies include (1) enzyme production, (2) substrate conditioning, (3) saccharification, (4) fermentation process development, (5) saacharification reactions, (6) the process control system, and analysis to determine if an economically viable process for enzymatic conversion of cellulose to glucose can be developed.	Interagency agreement (IAG-05-0758)	U.S. Army, Natick Laboratories	$100,000	4/75	1/77 Annual report in draft stage
Acid Hydrolysis for Biological Conversion Research is underway to develop and optimize a novel pretreatment hydrolysis process for the conversion of waste cellulose to glucose. The bench-scale results have been extremely promising, and a mini-plant is under construction to prove scale-up.	Grant (R803664-02)	New York University	$110,000	6/75	12/79

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
Methane Recovery from Sanitary Landfills Explore the feasibility of designing and operating landfills for the controlled production and recovery of methane.	Contract (RFP CI-76-0308)	To be selected	N. A.	10/76 (est.)	10/77 (est.)
Methane Recovery from Sewage Treatment Systems Evaluate sewage treatment system for production and recovery of methane utilizing the anaerobic digestor.	Contract (68-03-2356)	Environmental Systems, Inc.	$ 30,000	6/75	9/76 Draft report under review
Energy Requirements of Sewage Treatment Plants Evaluate energy requirements for sewage treatment plants and feasibility of energy recovery from sludge.	Contract	Clean Water Consultants	$ 25,000	4/75	9/76 Draft report under review
Use of Organic Residues in Sewage Sludge Processing Project consists of bench- and pilot-scale testing to define the process, economics, and feasibility of using a mixture of sewage sludge and the organic rejects from material recovery operations using the Franklin, Ohio, system to improve the dewatering characteristics of the sludge. Resulting dewatered sludge is being investigated to determine if methane and/or a solid fuel can be produced. Gas mixing studies for anaerobic digestion have been completed. Final report published on the effects of selected gas mixing system on large scale anaerobic digestion.	Contract (68-03-2105)	Systems Technology Corp.	$271,998	6/28/74	8/30/77
Co-Incineration of MSW and Sewage Sludge RDF will be used as principal fuel in a sludge incinerator. Environmental, technical, and economic evaluations of RDF as a fuel for sludge incineration will be made.	Grant (E-803927)	Twin Cities Metropolitan Waste Control Commission	$275,000	6/75	8/77

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
Co-Disposal of Sewage Sludge and Municipal Refuse This project is to demonstrate the ability of the Union Carbide Purox pyrolysis system to process a mixture of sewage sludge and solid waste. The organic materials will be converted into a medium Btu fuel gas.	Grant (S-803769)	City of South Charleston	$332,000	9/76	10/77
Compilation, Development, and Testing of Interim Standard MSW Product Analysis Procedures Develop optimum sampling and analysis procedures for characterizing materials recovered from MSW; develop and test user specifications for selected secondary material feedstocks. The results will serve the development of specifications for recovered materials and product quality control, both of which are vital elements in removing market barriers.	Contract	To be selected	N. A.	8/76	12/78
Alternatives for Utilization of Waste Rubber Tires Cost/benefit analysis of alternative systems for the management of waste passenger car tires.	Contract (68-03-2401)	California State University	$ 18,000	4/76	2/77
Field Evaluation of Waste Rubber in Road Pavement This project will experimentally evaluate rubberized asphalt derived from waste tires as a road paving material; it will be conducted in conjunction with D.O.T.	Interagency agreement	Federal Highway Administration	$ 82,000	3/76	3/81
Waste Glass Used in Brick Manufacturing Conduct a field evaluation of waste glass use in fabricating bricks; also evaluate glass-brick production.	Contract	Occidental Research	$ 35,000	7/76	10/77

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
Develop and Test Candidate Building Materials from Solid Waste Purpose of this project is to evaluate previous research on potential products from waste materials; to develop data on supply and location of waste materials; to demonstrate feasibility, applicability, and acceptance of building products fabricated from waste materials.	Contract (68-03-2056)	Materials Systems Corp.	$188,000	2/74	10/77
State-of-the-Art Report on Land Cultivation and Refuse Farming A survey of the literature on techniques by which wastes from selected industries and municipal refuse are added to the soil. The beneficial and detrimental aspects will be evaluated and a techno-economic evaluation performed.	Contract (68-03-2435)	SCS Engineers	$ 88,000	7/76	9/77
Upgrading of Pyrolysis Products Research to produce higher molecular weight hydrocarbons during pyrolysis and from lower molecular weight products derived from the pyrolysis of municipal solid wastes using chemical methods.	Interagency grant (IAG-D5-0781)	U.S. Navy, Naval Weapons Center	$235,000	6/75	6/77
Upgrading of Oils Derived from the Pyrolysis of Agricultural Wastes Investigation of physical methods for the upgrading of oils produced from the pyrolysis of agricultural and municipal wastes to produce products of improved marketability.	Grant (804416)	Georgia Institute of Technology	$ 61,000	6/76	8/78
Conversion of Char to Useful Products Investigate and develop a process for char gasification as a feedstock for chemicals or fuels production.	Interagency agreement (IAG-D5-0646)	ERDA, Los Alamos Scientific Laboratories	$243,000	9/75	8/77
Development of Methods for Stabilization of Pyrolysis Oils Research investigations of chemical mechanisms influencing oil viscosity during and just after oil production.	Grant (R-804440)	Atlanta University	$ 65,000	6/76	8/78

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
Environmental Assessments of Waste-as-Fuels Processes A long-term contract to provide continuing services: (a) to establish environmental assessment methodology; (b) to identify, and develop as needed, measurement techniques; (c) to perform evaluations of selected processes.	Contract	To be selected	N. A.	9/76	9/78
Control Technology for Emissions from Resource Recovery Systems Assess and develop pollution control technology for waste-as-fuels processes, including preprocessing and conversion systems.	Contract	To be selected	N. A.	N. A.	N. A.
Incentive Pricing of Collection Services as a Resource Recovery Tool Develop an experimental design to determine the effects of incremental pricing on solid waste management.	Contract	To be selected	N. A.	8/76	10/77
Futures Markets for Reclaimed Materials Investigate the feasibility of establishing scrap futures markets for selected reclaimed materials.	Grant (R-804309)	Environmental Law Institute	$ 67,000	6/76	8/77
Technical/Economic Assessments of Waste-as-Fuel Processes Evaluate technical and economic aspects of competing waste-as-fuel processes, based on state-of-the-art knowledge of the environmental characteristics of the processes. Competing waste-as-fuel processes options including co-firing of waste and fossil fuels, waste incineration with heat recovery, direct conversion of waste to electricity, pyrolytic conversion, bioconversion, etc., will be assessed.	Contract	Ralph M. Parsons Co.	$267,000	5/75	12/76 Draft report due in Oct.

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RESEARCH AND DEVELOPMENT: MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY AND INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY, CINCINNATI, OHIO (CONTINUED):					
Technology Transfer Reports on RDF/Coal Co-Firing Reports that will aid in transferring the technology to potential users.	Contract	To be selected	N. A.	N. A.	N. A.
Single-Cell Protein Production by Bioconversion of Waste Materials	Contract (68-03-2395)	Ebon Research Systems	$ 20,000	3/23/76	12/27/76 Draft report under review
U.S. DEPARTMENT OF COMMERCE:					
Characterization of Paper Pulp Fibers The energy consumed in papermaking can be reduced by recycling of more scrap. To do this, however, requires the development of better and faster pulp characterization methods. The project is developing the optical and analytical means for doing this.	In-house	National Bureau of Standards	$ 87,000 (ERDA funding)	FY 1976	FY 1981 (Report due Oct. 1976)
Materials Flows Analysis Development of comprehensive data bases and supporting computer programs to provide, for selected production sectors, a systematic array of process steps, input materials, labor, and power, and output products and process residuals. Process detail considers use of residuals as secondary materials inputs and distinguishes use of primary materials, prompt residuals, and obsolete recovered materials. Processes considered to date are for aluminum, ferrous scrap, and leather.	In-house	Quantitative Analysis Division, Bureau of Domestic Commerce		July 1975	Oct. 1977 or later
U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF MINES:					
Environmental Evaluation of Municipal Refuse as an Energy Resource Evaluation of the environmental impact of municipal refuse	Internal research	College Park Metallurgy Research Center, College Park, Md.	$100,000	FY 76	FY 77 In progress

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF MINES (CONTINUED):					
combustibles by determining the concentration of significant elements.					
Ferrous Scrap—Demand vs. Newly Available Supply, 1975-1985 To develop on a regional and periodic basis the requirements and future availability of ferrous scrap to determine whether balance, shortage, or surplus situations are expected during 1975-85.	Contract (JO155146)	A. T. Kearney, Inc., Chicago	$ 49,666	5/1/76	7/1/76 Final report in clearance process
Government Barriers to the Use of Secondary Ferrous and Nonferrous Materials To identify possible governmental barriers to the use of domestic secondary ferrous and nonferrous materials and to develop legislative proposals to eliminate these barriers.	Contract (JO155126)	JACA Corporation, Fort Washington, Pa.	$145,020	6/30/75	6/30/77 In progress
Mathematical Modeling of Raw Materials and Energy Needs of the Iron and Steel Industry in the U.S.A. Phase V Three major activities are planned: (1) effect of using direct reduction materials rather than pig iron as primary metallic supply for new steelmaking; (2) effects on scrap supply and energy requirements when steel industry operates at less than full capacity; and (3) effects on scrap supply and energy requirements if the steel industry is not able to increase capacity to meet anticipated rising demand for steel.	Contract (SO122079)	Massachusetts Institute of Technology, Dept. of Materials Science and Engineering	$ 43,500	6/1/76	5/31/77 In progress
Metallurgical Application of Magnetic Fields The project is directed toward advancing the technology of solid/solid and solid/liquid separations using ferrofluids by improved designs of separators and innovations in fluid preparation.	Internal research	Twin Cites Metallurgy Research Center	$155,000	FY 1976	FY 1977 In progress

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF MINES (CONTINUED):					
Recovery of Nonferrous Metals From Auto Shredder Refuse Development of hydrometallurgical methods for separating mixed nonferrous metals, mainly zinc, aluminum, and copper, obtained from the nonmagnetic refuse generated during the shredding of junk automobiles.	Contract (GO133080)	Stanford University	$ 27,298	6/30/73	10/1/76 In progress
Recycling Automotive and Other Scrap Development of improved methods and equipment for the recovery and subsequent recycling of metals and plastics from junked automobiles and other scrap sources.	Internal research	Salt Lake City Metallurgy Research Center	$287,000	FY 1975	FY 1976 In progress
Refining Secondary Nonferrous Metals Development of improved extractive processing methods that will increase the utilization of secondary nonferrous metals and advance resource recovery technology.	Internal research	College Park Metallurgy Research Center	$362,000	FY 1971	Continuing
Secondary Resource Recovery The project is directed toward the adoption of resource recovery as a system for solid waste management by demonstrating the technical and economic feasibility of continuous mechanical systems for separating incinerator residues, urban refuse, including white goods and bulky refuse, into its metal, mineral, and energy values, and to upgrade crude products into forms suitable for recycling.	Internal research	College Park Metallurgy Research Center	$663,000	FY 1970	FY 1977 In progress
Utilization of Mining and Milling Wastes Investigation of the utilization and/or disposal of copper, lead-zinc tailings, iron ore waste products, coal fly ash, phosphate slimes, redmuds from bauxite processing, steel slags, foundry dusts, steelmill dusts,	Contract (JO155141)	ITT Research Institute, Chicago	$ 30,410	6/4/75	1/3/77

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF MINES (CONTINUED):					
nonferrous metal industry dusts, and a host of metal- and mineral-based waste products such as waste glass, tin cans, junk cars, metal plating wastes, and other metal- and mineral-containing solutions and sludges.					
U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION:					
Activated Carbon for Sludge Digestion Laboratory and small pilot-scale development of a process to enhance anaerobic digestion by addition of activated carbon. Methane yield increased 3-6 times by process. If successful, several agencies may conduct full-scale tests.	Contract	Battelle Pacific N.W. Lab.	$467,000	April 1976	Oct. 1977
Ammonia From Urban Wastes Support for preliminary design and feasibility work of what will be a $101 million project using the Union Carbide "Purox" pyrolysis process to produce a fuel gas rich in hydrogen and carbon monoxide which will feed an ammonia synthesis plant.	Contract (E45-1-2331)	City of Seattle	$500,000	May 1976	Jan. 1977
Anflow Joint project between ERDA, the Norton Co., and the City of Oak Ridge to install a packed bed anaerobic digester at the city's sewage treatment plant. On a laboratory scale, process shows promise of reducing drastically the cost of sewage treatment plants and the waste sludge disposal problem. Technology can be extended to industrial wastes, and, by tailoring organisms, it can produce alcohols and other chemicals.	Contract (05-ENG-26)	Oak Ridge National Lab.	$670,000 ($520,000 ERDA)	April 1976	Sept. 1978
Cofiring in Cement Kiln Light fraction of urban solid waste will be reduced to ash, analyzed, and its effect on cement clinker determined. In addition, light fraction of urban waste will be burned on an extended basis (72 hours vs. 8 hours to date) in a cement kiln fired with natural gas.	Contract (E40-1-5150)	Browning-Ferris Inc., Portland Cement Assn., Gulf Coast Portland Cement Co.	$670,000	July 1976	Jan. 1978

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (CONTINUED):					
Conversion of Cellulosic and Waste Polymer Material to Gasoline Laboratory research to develop a two-stage process: (1) pyrolytic conversion of wastes to produce an optimum mix of off gases; (2) synthesis reaction to produce a liquid fuel.	Contract (E11-1-2982)	Arizona State University	$ 80,000	June 1976	June 1978
Digester Mixing Tests Project uses an existing anaerobic digester and urban waste separation plant to develop a high solids concentration (10%) substrate. Principal project thrust is in mechanical mixing at high solids content. Is coordinated with EPA project on gas mixing at low solids content.	Contract (E40-1-5175)	Systems Technology Corp.	$ 90,000	Sept. 1976	July 1977
Development of a Glass-Polymer Sewer Pipe from Waste Glass Laboratory research to supplement current limited data by fabrication of additional specimens and tests. Field installations will be evaluated; energy and economic impact will be determined.	Contract (30-1-0016)	Brookhaven National Lab.	$ 75,000	April 1976	Aug. 1977
Energy and Protein Production from Pulp Mill Wastes Laboratory research to convert spent sulfite liquor to a biodegradable form. Ozonation will be used to desulfonate the lignin, thus promoting follow-on biological digestion. Three digestion processes will be optimized: yeast protein production, methanization, and anaerobic digestion of final residues. Engineering-economic data for design scale-up will be determined.	Contract (E11-1-2983)	Michigan Technological University	$235,000	May 1976	May 1979
Enzymatic Hydrolysis Process uses an enzyme produced by a yeast-like organism to convert cellulose to glucose. The glucose may be fermented to ethanol, converted to sorbitol, digested to methane, or used as a chemical feedstock.	Contract (E49-28-1007)	U.S. Army Laboratories, Natick	$1,390,000	Jan. 1976	Sept. 1977

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (CONTINUED):					
High Rate Anaerobic Digestion Laboratory work to explore the theory of the rate limitation of anaerobic digestion being the transfer phase of methane, and to explore means to improve that phase to include less viscous fluids and operation under a vacuum.	Contract (E11-1-2900)	Natural Dynamics	$183,000	June 1976	May 1978
Household System Development of a system to provide partial home heating and cooling from household wastes and to reduce water consumption. A study to catalog and assess the available systems for individual homes and define the institutional barriers that should be more deeply assessed.	Contract (E11-1-3036)	General Electric	$100,000	Sept. 1976	March 1977
Methane Production from the Anaerobic Treatment of Industrial Wastewater Laboratory research to evaluate a selected set of organic industrial wastes in terms of methane yield.	Contract	Drexel University	$69,000 (FY 76 funded by NSF)	July 1974	June 1977
Pompano Beach: Advanced System Experimental Facility Urban waste is shredded and the light and heavy fractions separated in an air classifier. The lights (mostly organics) are then fed with 5% sewage sludge solids and nutrients to an anaerobic digester where a biological process converts them to methane-rich gas.	Contract (E11-1-2770)	Waste Management Inc.	$2.96 million (construction phase only; 2-4 yr. test phase to follow)	June 1975	Nov. 1977
Regional Study A study of the effect of various elements on waste characterization and quantification and to recommend future ERDA research.	Contract (E11-1-4011)	Resources Planning Associates	$15,000	June 1976	Dec. 1976
European Assessment The contractor will first assess the status of European technology, primarily waterwall incinerators. Then case histories and economic, operating, and technical data will be gathered	Contract (E49-18-2103)	Resources Planning Associates	$100,000	June 1976	Jan. 1977

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (CONTINUED):					
on the Munich systems and at least three others. Finally, the economics will be translated to the U.S. if implementation seems feasible.					
Support of Equipment Test and Evaluation Facility The equipment test and evaluation facility assembles and tests various components of trash preprocessing equipment. In addition, the contractor works with resource users to develop specifications for recovered materials to optimize use.	Contract (E49-1-3851)	National Center for Resource Recovery	$250,000	Sept. 1976	May 1978
Tests of Pyrolysis Gases Pilot size (2,000 CFM) gas conditioning train and shift reactors will be installed and operated on the fuel gas produced by a 200-TPD Purox pyrolysis reactor. This phase aims at re-forming the resultant hydrogen to ammonia.	Contract (E49-1-2116)	Union Carbide, Linde Division	$1 million	Aug. 1976	July 1977
Utilization of Waste Carbon Monoxide as a Chemical Feedstock A study to determine the feasibility of, and opportunities for, utilizing waste CO from basic industries as a replacement for natural gas as a chemical feedstock. Industrial sources will be identified and evaluated. The most promising configurations will be subject to economic analysis.	Contract (45-1-1830)	Battelle Pacific N.W. Labs.	$380,000	April 1976	May 1978
Characterization, Measurement, and Monitoring of Organic and Inorganic Pollutants Derived from Energy Generating Sources Laboratory study and field confirmation to develop techniques and instrumentation needed for characterizing organic and inorganic pollutants in effluents from energy-generating sources, with special emphasis on the Ames Solid Waste Recovery System and Municipal Power Plant use of refuse-derived fuel as a supplemental fuel with coal.	Contract (W-7405-ENG-82)	Ames Laboratory, Iowa State Univ.	$120,000	7/1/75	Oct. 1978

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (CONTINUED):					
Atmospheric Sciences—Environmental Effects of Solid Wastes Program conducted in cooperation with EPA and the City of Ames Municipal Power Plant and Solid Waste Recovery System for the purpose of determining the environmental effects of change in fuel composition. Particular emphasis is placed on organics in stack emissions and on the effect of boiler size, type of fuel injection and burners, and type of particulate removal system in relation to the fuel composition and boiler load.	Contract (W-7405-ENG-82)	Ames Laboratory, Iowa State Univ.	$136,000	7/1/75	Oct. 1978
Study of Microbiological Air Quality in Relation to the Ames Municipal Solid Waste Disposal and Energy Recovery System Microbiological samples will be taken at 11 locations throughout the Ames solid waste recovery facility to determine the total number and types of bacteria, yeasts, molds, and viruses that may be present and to determine whether any may be potentially pathogenic. Ambient levels around Ames will also be determined.	Contract (W-7405-ENG-82)	Ames Laboratory, Iowa State Univ.	$69,000	10/1/76	Oct. 1978
Environmental Control Requirements in Solid Waste Processing and Energy Recovery Facilities (Water Pollution) Paper study to assess the efficacy and practicability of water pollution control equipment to treat process water for urban waste utilization systems. Recommendations will be made to ERDA for further studies, surveillance activities, and/or needed RD&D programs.	Contract (W-7405-ENG 82)	Ames Laboratory, Iowa State Univ.	$100,000 (Proposed)	10/1/77	Sept. 30, 1978
FEDERAL ENERGY ADMINISTRATION:					
Energy and Economic Impacts of Mandatory Deposits Examines energy, capital, jobs, and labor earnings impacts of mandatory deposits for beverage containers.	Contract (CO-04-50175-00)	Research Triangle Institute	$100,000		Fall 1976 Final report under review

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
FEDERAL ENERGY ADMINISTRATION (CONTINUED):					
Feasibility in Modular Integrated Utility System As part of its MIUS program, HUD is constructing a demonstration site consisting of 486 multi-family dwelling units in six structures, two schools, swimming pool, and 50,000 square feet of commercial area in Jersey City, N.J. FEA has contracted with HUD to examine the feasibility of and design a waste heat recovery incinerator to be installed in the Jersey City site.	Interagency agreement (14-01-0001-2056)	Department of Housing and Urban Development	$150,000	6/28/74	Fall 1976 Draft final report under review
Feasibility of Utilizing Agricultural Wastes as an Energy Source The latent energy in agricultural wastes, crop residues, and manures that are dissipated each year is approximately 6 quads. However, because of the dispersion of the wastes it may be feasible from both an economic and energy standpoint to process only a small percentage of the wastes. This study has been subdivided into five smaller studies:	Interagency agreement (CG-04-50097-00)	Agricultural Research Service, U.S. Dept. of Agriculture	$250,000 (Including $100,000 from FEA and $150,000 from National Science Foundation)	5/23/76	Fall 1976 Draft final reports in preparation or review
1. Small-scale processes that an individual farmer could use to extract energy from wastes.		West Virginia University			
2. Ways energy could be extracted from rice hulls.		University of California at Davis			
3. Anaerobic methane fermentation.		Iowa State University			
4. Production of methane or alcohols from bagasse.		University of Florida			
5. Process for converting forest residues to energy products.		U.S. Forest Service			

Title and description	Type	Performing organization	Amount	Beginning date	Ending date or current status
FEDERAL ENERGY ADMINISTRATION (CONTINUED):					
Overcoming Institutional Barriers to Solid Waste Utilization as an Energy Source The purpose of this study is to identify the institutional barriers preventing the utilization of urban refuse as an energy source and develop initiatives to overcome these barriers.	Contract (CO-04-50172-00)	Gordian Associates	$92,000	6/4/75	Fall 1976 Final report in preparation
Resource Recovery From Municipal Solid Waste—Feasibility Study The study is examining the feasibility of adapting one or more of TVA's steam plants to burn refuse as a supplementary fuel as in St. Louis. TVA is the largest steam utility in the country and would be a trend setter. One aspect of the study is also examining the economic feasibility of generating methane or methanol from the waste and using it as peaking turbine fuel.	Interagency agreement (CG-04-50063-00)	Tennessee Valley Authority	$400,000 (Utilities—$40,000; EPA—$100,000; FEA—$40,000; TVA—$220,000)	5/2/75	Fall 1976 Revised final report in preparation

Appendix E

BIBLIOGRAPHY ON ENVIRONMENTAL AND NATURAL RESOURCE IMPACTS OF PRODUCTS AND MATERIALS

The application of material and energy balance concepts to broad sectors of the economy–entire industries, consuming sectors, or the economy as a whole–has given rise since the late 1960's to a new literature on the comparative natural resource and environmental implications of alternative raw materials, fuels, and product designs. The broader systems viewpoint has brought an increasing awareness to both public and private sector decision-makers of the extremely complex and interrelated nature of our various systems of production in terms of their impacts on resource demands and environmental quality.

The emerging body of literature includes a variety of types. Some authors have focused on a particular raw material or energy form, others on finished products or groups of products; some have been concerned primarily with particular residuals (air or water pollutants or solid wastes), while others have dealt with a broad spectrum of emissions and effluents. Some have been directed at material and energy use from a conservation or supply, rather than an environmental quality, viewpoint.

The more comprehensive studies have sometimes been referred to as "resource and environmental profile analyses" (REPA) of materials and products. They all deal with relatively broad conceptual systems that attempt to trace material and energy flows from raw material and energy extraction to some later point of product manufacture and even, in many cases, through product use and disposal. Some have focused on comparative sequences for virgin and secondary raw materials supplies or single-use versus multiple-use products and containers.

The following bibliography was prepared by an EPA consultant, Dr. Arthur Purcell of George Washington University, in late 1975. It is considered to be a reasonably complete listing of nonproprietary research published through 1975 on the comparative natural resource, energy, and environmental impacts of materials and products which are significant in the municipal solid waste stream.

FINISHED PRODUCTS: PAPER, PLASTICS, STEEL, GLASS, ALUMINUM, COMBINATION, AND OTHER (WOOD, CONCRETE, ETC.)

Bailie, R. C., B. T. Riley, Jr., and R. Zaltzman. Environmental impact assessment of polyvinyl chloride as a packaging material for distilled spirits. Washington, U.S. Treasury Department, Bureau of Alcohol, Tobacco and Firearms, 1973. 257 p. (Distributed by National Technical Information Service, Springfield, Va., as EIS-AA-73-0477-F-2.)

Berry, R. S., and H. Makino. Energy thrift in packaging and marketing. *Technology Review*, 76(4):33-43, Feb. 1974.

Berry, R. S., and M. F. Fels. The energy cost of automobiles. *Science and Public Affairs–Bulletin of the Atomic Scientists*, 29(10):11-17, 58-60, Dec. 1973.

Bingham, T. H., et al. [Research Triangle Institute]. An analysis of the materials and natural resource requirements and residuals generation of personal consumption expenditure items. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Cross, J. A., et al. [Midwest Research Institute]. Plastics; resource and environmental profile analyses. Washington, Manufacturing Chemists Association, June 28, 1974. 104 p.

Dane, C. W. Energy requirements for wood and wood substitutes and the "energy crises." Corvallis, Oreg., U.S. Forest Service, Division of Forest Economics and Marketing Research, June 1, 1972. 17 p. (Unpublished report.)

Energy and technical development. Greenwich, Conn., American Can Company, 1975. 14 p., app. [Slide narrative.]

Gordian Associates, Inc. An energy analysis of the production of selected products in six basic material industries. U.S. Environmental Protection Agency, 1975. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Gordian Associates, Inc. Environmental impacts associated with selected options for the recycling of materials, reuse of products and recovery of energy from solid waste. U.S. Environmental

Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Gordian Associates, Inc. Environmental impacts of production of virgin and secondary paper, glass and rubber products. Environmental Protection Publication SW-128c. U.S. Environmental Protection Agency. (In preparation; to be distributed by National Technical Information Service, Springfield, Va.)

Haller, G. L. Critique of specified beverage container environmental studies; final report to Monsanto Company. URIC Report 74-63. Wallingford, Conn., University Research Institute of Connecticut, Inc., Sept. 1974. 24 p.

Haller, G. L. [Monsanto Company]. Resource utilization and environmental impact of alternative beverage containers. Presented at Symposium: Environmental Impact of Nitrile Barrier Containers, Hartford, Conn., July 19, 1973. 2 v.

Hannon, B. System energy and recycling; a study of the beverage industry. CAC Document No. 23, rev. Urbana, University of Illinois, Center for Advanced Computation, Mar. 17, 1973. 26 p.

Hickman, H. J., R. Lewis, and J. Salomonson. [University of Minnesota, Institute of Technology]. A study of the environmental impact of polystyrene vs. paper pulp egg cartons and meat trays. Hopkins, Minn., Red Owl Stores, Inc., Mar. 1972. 14 p., app.

Hunt, R. G., et al. [Midwest Research Institute]. Resource and environmental profile analysis of nine beverage container alternatives; final report. v. 1-2. Environmental Protection Publication SW-91c. Washington, U.S. Environmental Protection Agency, 1974. 178 p.

Hunt, R. G., and R. O. Welch. [Midwest Research Institute]. Resource and environmental profile analysis of plastics and non-plastics containers; a summary. New York, The Society of the Plastics Industry, Inc., Nov. 1974. 36 p.

An investigation of the effects on society and the environment of alternative methods of food and beverage packaging. Presented at 1st Annual Meeting, Student Originated Studies Groups of the National Science Foundation, Philadelphia, Dec. 29, 1971. Urbana-Champaign, University of Illinois, N.S.F/S.O.S. Project. [60 p.], app.

Makhijani, A. B., and A. J. Lichtenberg. Energy and well-being. *Environment,* 14(5):10-18, June 1972.

Makino, H., and R. S. Berry. Consumer goods; a thermodynamic analysis of packaging, transport and storage. [Chicago], Illinois Institute for Environmental Quality, June 1973. 162 p.

Midwest Research Institute. Environmental impact analysis of eight beverage container systems; final draft report. v. 1. Washington, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Aug. 9, 1973. 39 p.

Midwest Research Institute. Environmental impact profiles for selected beverage containers; final report. Wilmington, Del., E. I. du Pont de Nemours & Company, Inc., Apr. 30, 1973. 2 v.

Sundström, G. Beverage containers and energy; investigation of energy requirements from raw material to garbage treatment for four Swedish beer packaging alternatives. Bjärred, Sweden, G. Sundström AB. 1 v. (various pagings).

METALS: BULK PRODUCTS

Bravard, J. C., H. B. Flora, II, and C. Portal. Energy expenditures associated with the production and recycle of metals. Report No. ORNL-NSF-EP-24. Oak Ridge, Tenn., Oak Ridge National Laboratory, Nov. 1972. 87 p.

Franklin, W. E., et al. [Midwest Research Institute]. Potential energy conservation from recycling metals in urban solid wastes; final report. Washington, The Energy Policy Project, May 30, 1974. 75 p.

Makhijani, A. B., and A. J. Lichtenberg. An assessment of energy and materials utilization in the U.S.A. Berkeley, University of California, Electronics Research Laboratory, Sept. 1971. 42 p.

Ziegler, R. C., et al. [Calspan Corporation]. Environmental impacts of virgin and recycled steel and aluminum. Environmental Protection Publication SW-117c. U.S. Environmental Protection Agency, 1976. 125 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-253 487.)

PLASTICS: BULK PRODUCTS

Baum, B., and C. H. Parker [DeBell & Richardson, Inc.]. Plastics waste management. Washington, Manufacturing Chemists Association, Oct. 1974. 113 p., app.

Berry, R. S., T. V. Long, II, and H. Makino. Energy budgets: 5. An international comparison of polymers and their alternatives. *Energy Policy,* 3(2): 144-155, June 1975.

Kaufman, F. S., Jr. Opportunities for plastics in resource recovery. Presented at National Materials Conservation Symposium No. 1, Resource Recovery and Utilization, National Bureau of Standards, Gaithersburg, Md., Apr. 29, 1974. 15 p.

Proceedings; Symposium on Environmental Impact of Nitrile Barrier Containers; LOPAC: a case study, Hartford, Conn., Rensselaer Polytechnic Institute, July 19, 1973. Hartford, Conn., Monsanto Company and the University Research Institute of Connecticut. 178 p.

PAPER: BULK PRODUCTS

Arthur D. Little, Inc. Energy consumption in the production of selected grades of paperboard. [Kalamazoo, Mich.], Boxboard Research and Development Association, June 1973. 12 p.

Franklin, W. E. Paper recycling—the art of the possible, 1970-1985. New York, American Paper Institute, 1973. 181 p.

Franklin, W. E., R. G. Hunt, and J. B. Maillie. [Midwest Research Institute]. Environmental impacts of paper manufacture. *In* Policy background study on resource recovery—comparative economic and environmental analysis of

materials recycling vs. virgin materials manufacture for paper, glass and steel. Washington, Council on Environmental Quality, Dec. 1971. p. 48-92. (Unpublished draft report.)

Hunt, R. G., and W. E. Franklin. Environmental effects of recycling paper. MRI 1106. Presented at 73d National Meeting of the American Institute of Chemical Engineers, Minneapolis, Aug. 27-30, 1972. Kansas City, Midwest Research Institute, [July 1973]. 34 p.

An investigation of the economic and environmental benefits of recycling as exemplified in corrugated box manufacture. New York, Gordian Associates, Feb. 1, 1973. 64 p., app.

Midwest Research Institute. Combination paperboard and solid bleached kraft paperboard—comparison of costs and environmental impacts; final report. Kalamazoo, Mich., Boxboard Research and Development Association, Dec. 1, 1972. 44 p.

Reding, J. T., and B. P. Shepherd [Dow Chemical Company]. Energy consumption: paper, stone/clay/glass/concrete, and food industries; final report Aug. 1974-Mar. 1975. U.S. Environmental Protection Agency, Apr. 1975. 60 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-241 926.)

RELATED PAPERS OF INTEREST

Arthur D. Little, Inc. Economic impact of anticipated paper industry pollution abatement costs. Pt. 3. Economic analysis. Washington, Council on Environmental Quality, Nov. 1971. 70 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-207 146.)

Atkins, P. R. Recycling can cut energy demand dramatically. *E/MJ* [Engineering and Mining Journal], 174(5):69-71, May 1973.

Ayres, R., J. Saxton, and M. Stern [International Research and Technology Corporation]. Materials-process-product model; a feasibility demonstration based on the bottle manufacturing industry; final report IRT-305-FR. [Washington], National Science Foundation, July 9, 1974. 1 v. (various pagings).

Baillie, R. C., B. T. Riley, Jr., and R. Zaltzman. PVC bottles score in environmental test. *Modern Plastics*, 50(7):52-58, July 1973.

Ballard, D. W. An American view of problems of materials conservation. *ASTM* [American Society for Testing and Materials] *Standardization News*, 3(1):26-32, Jan. 1975.

Bever, M. B. Raw materials: energy and environmental constraints. *Science*, 185(4146):99, July 12, 1974. [Letter to the editor.]

Bower, B. T., and D. J. Basta. Residuals-environmental quality management; applying the concept. Baltimore, Johns Hopkins University, Center for Metropolitan Planning and Research, Oct. 1973. 88 p.

Brooks, D. B., and P. W. Andrews. Mineral resources, economic growth, and world population. *Science*, 185(4145):13-19, July 5, 1974.

Bullard, C. W., III, and R. A. Herendeen. Energy impact of consumption decisions. CAC Document No. 135. Urbana, University of Illinois, Center for Advanced Computation, Oct. 1974. 32 p.

Claussen, E. L. Packaging source reduction; can industry and government cooperate? Environmental Protection Publication SW-136. Washington, U.S. Environmental Protection Agency, Oct. 1974. 17 p.

Conservation in materials utilization; a report of the Federation of Materials Societies for the National Commission on Materials Policy. *Materials Evaluation*, 31(4):1r-28r, Apr. 1973.

Duke, J. M. Patterns of fuel and energy consumption in the U.S. pulp and paper industry. [New York], American Paper Institute, Mar. 1974. 23 p., app.

Energy and Environmental Analysis, Inc. Energy management in manufacturing; 1967-1990. v. 1. Summary report. Washington, Council on Environmental Quality, Aug. 1, 1974. 84 p.

Folk, H., and B. Hannon. An energy, pollution and employment policy model. CAC Document No. 68. Urbana, University of Illinois, Center for Advanced Computation, Feb. 10, 1973. 18 p.

Gordian Associates Inc. Potential for energy conservation in nine selected industries; the data base. Washington, U.S. Federal Energy Administration, June 1974. 505 p.

Gyftopoulos, E. P., L. J. Lazaridis, and T. Widmer. Potential fuel effectiveness in industry. Cambridge, Mass., Ballinger Publishing Company, 1974. 89 p. (Energy Policy Project of the Ford Foundation.)

Harris, J. F. Role of total process concepts in evaluating pulping research. Madison, Wis., U.S. Forest Service, Forest Products Laboratory, Apr. 1975. 7 p., app.

Hunt, R. G., and T. C. Kennel. The concept of total environment impact analysis for competitive materials and uses and environmental costs of selected packaging plastics. Presented at 74th National Meeting, American Institute of Chemical Engineers and the 7th Petrochemical and Refining Exposition, New Orleans, Mar. 15, 1973. 15 p.

Impact of energy costs, environmentalism, and technological change upon raw materials competition. Enfield, Conn., DeBell & Richardson, Inc., June 1974. 1 v. (various pagings).

Lowe, K. E. Recyclers claim environmental benefits for secondary fibers. *Pulp and Paper*, 48(1):70-72, Jan. 1974.

Lowe, R. A., M. Loube, and F. A. Smith. Energy conservation through improved solid waste management. Environmental Protection Publication SW-125. Cincinnati, U.S. Environmental Protection Agency, 1974. 39 p.

Meyers, P. G. The potential for energy conservation in the pulp and paper industry. *Paper Trade Journal*, 159(7/8):68-71, Feb. 17/24, 1975.

Midwest Research Institute. Studies assessing Federal energy research and development programs in the

areas of environmental effects, environmental control technology and energy conservation. Washington, Council on Environmental Quality, Apr. 9, 1975. 13 p., app.

No deposit, no return; a report on beverage containers. Albany, N. Y., State Senate, Task Force on Critical Problems, Feb. 1975. 106 p., app.

Myers, J. G. et al. Energy consumption in manufacturing. Cambridge, Mass., Ballinger Publishing Company, 1974. 656 p. (Energy Policy Project of the Ford Foundation.)

Newman, D. K., and D. D. Wachtel. The American energy consumer. Cambridge, Mass., Ballinger Publishing Company, 1975. 384 p. (Energy Policy Project of the Ford Foundation.)

Poole, A. Potential energy recovery from organic wastes; first draft. [New York], Ford Foundation, Energy Policy Project, June 13, 1974. 143 p. (Unpublished report.)

Samtur, H. R. Glass recycling and reuse. IES Report 17. Madison, University of Wisconsin, Institute for Environmental Studies, Mar. 1974. 100 p.

Schipper, L. Energy conservation: its nature, hidden benefits and hidden barriers. *In* American Chemical Society. Energy and environment: the chemical viewpoint. (In preparation.)

Simms, W. C. Ecology ratings—a new frontier. *Modern Packaging*, 47(7):18-21, July 1974.

Slinn, R. J. Sources and utilization of energy in the U.S. pulp and paper industry. New York, American Paper Institute, 1973. 17 p.

Stanford Research Institute. Patterns of energy consumption in the United States. [Prepared for the Office of Science and Technology, Executive Office of the President.] Washington, U.S. Government Printing Office, Jan. 1972. 156 p., app.

Welch, R. O., W. E. Franklin, and R. G. Hunt. Resource and environmental profile analysis of solid waste disposal and resource recovery options. MRI Reprint 1158. Kansas City, Mo., Midwest Research Institute, June 1974. 30 p.

Williams, R., *ed.* The energy conservation papers. Cambridge, Mass., Ballinger Publishing Company, 1975. 416 p. (Energy Policy Project of the Ford Foundation.)

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